HANDY OUTLINES

GEOLOGY

THE EARTH'S CRUST

OF USEFUL KNOWLEDGE

THE EARTH'S CRUST:

A HANDY OUTLINE OF GEOLOGY.

BY

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PREFACE.

I HAVE long entertained the idea of a series of Useful Outlines. Twenty years' experience in lecturing to miscellaneous audiences has convinced me that what is primarily required for the diffusion of knowledge is less a full and systematic explanation than a pleasant and perspicuous outline. Details and reasonings, however methodical, become irksome to minds untrained to research; they are worse than useless to those who have neither the leisure nor the necessity to acquire them. There are thousands—young men striving after self-instruction; men in business, whose time will merely permit a cursory acquaintance with a subject; the leisurely, who seek information simply as an accomplishment; and the gentler sex, unprepared for technicalities—all anxious to read and learn, were the facts only presented to them in a handy and intelligible form. The information conveyed by such an outline may not be very extensive; but if it be accurate as far as it goes, it is so much gained of itself, and becomes the

surest basis for further acquisitions. Should the reader stop short at this stage, he has at all events a certain stock of available knowledge; and should he be stimulated by what he has acquired to proceed still further,—which in a majority of instances will be the case,—he has had the best preparation for this advancement.

Convinced of the utility of this plan, I commence the series with a Handy Outline of my own special study—an outline conveying in brief space such a knowledge of Geology as any well-informed mind would like to possess. Brief as it is, the sketch conveys a fair amount of information, and is specially prepared so as to stimulate the reader to the study of works of a fuller and more systematic character. Avoiding the plan of a text-book intended for students and professional inquirers, I have endeavoured to write as I would converse to an intelligent audience—dwelling on the leading facts, and explaining as I proceed any special or technical difficulty. Indeed, one of the main features of the volume is simplicity of treatment,—a feature indispensable in all elementary works, but particularly so in one devoted to such a recent and progressive science as Geology.

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I.

WHAT GEOLOGY AIMS AT.

OVER whatever portion of the globe we travel we find it made up of rocks and rocky substances. The dry land is composed of them, and, if we go to the sea-shore, we see them shelving away beneath the ocean, or rising up in mid-water as shoals, and reefs, and islands. Whether we pierce through the hills for railway tunnels, or sink into the plains for wells and coal mines, we pass alike through rocks differing in colour, composition, and consistence. The fair inference therefore is, that all the exterior or accessible portion of our planet consists of *rocks;* and under this term geologists comprehend, in a technical sense, all mineral substances, whether loose and shifting like sand, soft and plastic like clay, or hard and crystalline like marble.

These rock-matters, as the most casual observer must be aware, differ widely in different localities. In our own islands, for instance, if we dig for wells, or cut for railways, in and around London we meet with thick beds of sand, clay, and gravel; in Kent and Surrey the hills and high grounds consist of chalk; in Derbyshire they are chiefly limestones and marbles; in Durham and Northumberland we have sandstones, and coals, and ironstones;

in the neighbourhood of Edinburgh, hills of basalt and greenstone; in Forfarshire the prevailing rocks are red and gray sandstones; in Perthshire, as in Wales, we have abundance of roofing-slates; and in Aberdeenshire there are vast exhibitions of granites and granitic compounds. It must be obvious to the least reflecting, that there are causes in nature for this great variety and diversity of rock-substances; and to discover these causes and their modes of operation is one of the main objects of geological inquiry.

Again, when we investigate these rocks more closely, we find that a large proportion is arranged in beds or layers, one above another, like the courses in a building. Such a layer of rock is technically spoken of as a *stratum*, (from the Latin word *stratum*, strewn or spread out; plural, *strata*,) and rocks so disposed are said to be *stratified*. One cannot sink a well or pass through a railway cutting without observing this stratiform arrangement of the earth's materials; just as we see the

Stratified Rocks.

muds, and sands, and gravels of a river-estuary spread out, one above another, in a similar way. As nature now operates in laying down sedimentary matter, bed above bed, and layer above layer, in lakes, and estuaries, and seas, so we rightly infer that all stratified rocks, as sandstones, limestones, clays, and so forth, were formed in like manner through and by the agency of water. In other words, we regard the stratified rocks as the consolidated sediments of former ages; and geology endeavours, from an examination of their distribution, composition,

and character, to map out the areas of the waters in which, and the conditions under which, they were deposited.

Besides the stratified rocks, the observer will perceive another set, not arranged in layers, but rising up in hard and homogeneous masses. These are the granites, the basalts, and greenstones of our hills, in which no lines of sedimentary deposit appear, and which have evidently

Unstratified Rocks.

been formed in a way altogether different from the clays, and sandstones, and limestones already alluded to. When we turn to the burning mountain or volcano, and examine the lava that has been ejected during times of eruption, we find it cooled and solidified into rock-masses, so precisely analogous to basalts and greenstones, that it is sometimes even difficult to distinguish between them. Here, then, as in the former instance, the geologist is entitled to infer that the *unstratified* rocks have been produced in bygone ages just like the lavas of the present day, and he calls them *igneous*, as having been formed through and by the agency of fire, (Lat., *ignis*, fire.) As in existing nature, volcanic action, wherever it occurs, is accompanied by earthquakes and subterranean convulsions, which raise one portion of the ground and depress another, cause rents and fissures which are often filled with molten rock-matter, and produce irregularity and diversity of the land-surface; so geology endeavours to discover in the unstratified rocks their effects in creating hill-ranges, breaking up the stratified rocks, and every-

where producing irregularity and diversity in the solid framework of the globe.

Still further, on examining more intimately, the observer detects in many of the stratified rocks the petrified remains of plants and animals—stems, branches, leaves, and fruits of the one; and shells, crusts, scales, teeth, and bones of the other. In existing nature, plants and animals are drifted by rivers from the land and carried down to estuaries and the ocean, there to be entombed among their silts and sediments; and plants and animals, inhabiting the waters, die, and are imbedded in a similar manner in the same deposits. Applying his knowledge of the present to the interpretation of the past, the geologist examines and compares these petrified remains, and endeavours to arrive at a knowledge of the plants and animals to which they belonged—determining whether they inhabited the land or waters, whether they were freshwater or marine, and generally, the external or geographical conditions under which they grew and flourished.

By the means above enumerated,—namely, by an examination of the rocks themselves, the areas over which they are spread, their thickness and alternations, and the kind of plants and animals they contain,—the geologist strives to ascertain the past conditions of the earth, the various shiftings of sea and land, the life by which these were respectively peopled, and the geographical conditions that accompanied such mutations. In other words, he tries to read the history of our globe as contained in its rocky record—describing its external aspects at each successive stage in time, just as the geographer depicts its existing arrangements of sea and land with all their varied garniture of vegetable and animal existences. Geology is but the physical geography of former ages; and as the geographer deals with land and water, with plant life and animal life, and with the climates under which they flourish, so the geologist, who treats the same phenomena in bygone epochs, must be acquainted in some measure with the leading facts of mineralogy, botany, zoology, and meteorology.

The deciphering of the world's history in time constitutes the *theoretical* or *scientific* aspect of geology, and as such, presents an attractive and varied field of intellectual exercise. The repeated changes to which the earth's surface has been subjected, and the wonderful forms by which the land and waters have been successively peopled, must ever present sufficient attraction to the inquiring mind, while the observation its facts necessarily call forth, and the reasoning its problems require, must, in like manner, exalt geology to the position, perhaps, of the noblest and most comprehensive of the natural sciences. Beyond its theoretic interest, the science is also of vast *industrial* or *practical* importance. All the minerals and metals, the knowledge and use of which are so essential to the progress of civilisation, are derived from the earth. As these do not occur indiscriminately, but are found only in certain positions and associated with certain classes of rocks, it is indispensable to ascertain their position, their modes of occurrence, their abundance, and the facility with which they can be obtained. This geology alone can do with certainty and satisfaction; hence its great value to civilised nations, and especially to countries which, like Britain, derive so much of their importance from their mineral and metallic treasures.

Combining its theoretical and practical importance, geology has recommendations to its cultivation which few of the other sciences possess; and the only reason for its being less generally known is its comparative recentness as a study of exact observation and deduction. Till the commencement of the present century it can scarcely be said to have existed as a science; all before that period being mineralogy—a description of rocks, minerals, and crystals; or theories of the world, founded more in the imaginations of their authors than on the observation of facts as they occur in nature. Geology, as a world-history, was unknown: and men in general contented themselves with the patristic doctrine of the world's recent origin, and its subsequent re-moulding by the Noachian deluge. So soon, however, as it was discovered that its rocky structure had been subjected to

repeated physical change; that its strata contained the remains of innumerable creatures that had lived and died ages before the advent of man; and that its antiquity was not to be reckoned by centuries, but by cycles—then geology took its place as a science, and its course has ever since been rapidly and satisfactorily forward.

Such is the aim, scope, and character of geological inquiry. Its function is to read the history of our globe—tracing back, stage by stage, from the changes now taking place on its surface to those which occurred in bygone ages, and of which the only record lies deeply and often obscurely registered in its rocky structure. Geologists speak of this rocky structure as the "crust of the globe," distinguishing thereby all that we can see in precipices, ravines, and sea-cliffs, or reach by railway cuttings, mines, and coal-pits, from the "interior of the globe," of which we can know nothing by actual observation. The term was employed by the earlier cultivators of the science under the idea that the interior of the earth was in a state of molten fluidity; but it is now used simply as a convenient technicality for the exterior rocky structure accessible to our investigation, and without reference to any theory as regards the nature of the interior. On this crust are exhibited all the changes now effected by air and water, by rivers, waves, and tides, by earthquakes and volcanoes; and in the rocks of this crust are registered all the changes that took place through the same agencies in former ages. Every distinct set of rocks bespeaks a new arrangement of sea and land; every rock-structure indicates the mode of its formation; and every assemblage of organic remains reveals, less or more, the external conditions under which it flourished on the land or in the water. The crust of the globe, therefore, forms the wondrous record of world-history which science endea-

vours to reveal; it is the great storehouse of those minerals and metals which industry labours to apply to the utilities and luxuries of civilised existence. Geology has thus all the interest of a wondrous Past to attract; it possesses all the value of a sterling Present to incite to its study and acquirement.

II.

CAUSES OF GEOLOGICAL CHANGE.

IT has been stated in the preceding chapter that the earth's crust is mainly composed of stratified and unstratified rocks—the former produced through and by the operations of water, the latter through and by the agency of fire. It was further stated that the stratified rocks contained abundant remains of plants and animals in a petrified or *fossil* state (Lat., *fossus*, dug up)—these remains having been entombed in the strata when originally laid down as soft silt and sediment in the waters of deposit. These strata, produced at successive stages, and subsequently upheaved and disturbed by the volcanoes and earthquakes which discharged the unstratified rocks, necessarily imply change of condition and lapse of time; and the arrangement of these changes in orderly sequence is the great object of geology. But before we can rightly interpret these changes, and the times required for their accomplishment, we must understand the nature of the causes that produced them. And this brings us to a consideration of the belief that the causes now productive of stratified and unstratified rocks are the same in kind with those that produced them in bygone ages. In other words, we appeal from the present to the past, from the recent to the remote; and the better we understand the nature of the agencies now operating on the crust of the globe—winds, rains, frosts; springs, streams, rivers; waves, tides, currents; volcanoes, earthquakes, upheavals, and the like—the better will we be enabled to interpret the history of the stratified and unstratified rock-arrangements which have evidently been produced by similar modes of causation.

The causes now productive of geological change are usually arranged under five great heads:—The *Atmospheric* or *Meteoric*, operating chiefly through the medium of the atmosphere; the *Aqueous*, acting through and by the agency of water; the *Organic*, such as arise from the growth and decay of plants and animals; the *Chemical*, produced by the action and reaction of bodies upon each other; and the *Igneous* or *Vulcanic*, that result from some general and apparently deep-seated source of subterranean heat. At the present day these agents are incessantly active; and reasoning from the constitution and planetary relationship of the globe, we infer that they have been similarly active in all times past. Over local areas they may operate at one time with greater intensity than at another, and their results may also vary as they are situated within tropical, temperate, or arctic latitudes; but area for area, and latitude for latitude, we regard them as having acted ceaselessly and uniformly through all preceding ages. The manner in which they operate, and the geological results they produce, we shall now briefly indicate.

Under the Atmospheric or Meteoric are comprehended such agencies as winds, rains, frosts, and the like, which, though universal, act in intensity according to latitude, altitude, and other geographical conditions. Thus winds drift about all loose matter, and where blowing steadily or chiefly in one direction, (as the trade-winds,) must produce important results in carrying forward and piling up loose sands, like those of the sea-shores and the great deserts of Africa and Asia. In this way rivers may be obliterated and absorbed, valleys filled up, and tracts of fertile land overlaid and converted into barren hillocks or sand-dunes. Rains wear and wash away all loose and pulverulent material, and where soils are unprotected by herbage, or weathered rock-surfaces are exposed to their full force, great waste is every season accomplished through their agency. In our own islands, where the rain-falls are comparatively gentle, and do not exceed 30 or 40 inches in amount per annum, the waste is inconsiderable; but in tropical and sub-tropical latitudes, where the rain-

fall amounts to 100 or even 200 and 300 inches a year, and the torrents often sudden and heavy, their effects on the dry and parched surfaces is enormous—the streams running mud rather than water for days in succession. Of all the meteoric agents, frost is by far the most obvious and impressive in its results. Its full effects are felt within the polar circles, where land and water are all but perpetually ice-bound; in the temperate zones it occurs less or more every winter; and in all latitudes it is perennial above the snow-line. The water that lodges within the pores and chinks and fissures of rock-matter expands under frost, and thus separates the component parts, which, losing their cohesion when thaw comes, fall asunder and are disintegrated. This disintegration is sufficiently obvious in our own islands on all ploughed soils, road-cuttings, and rock-cliffs; but in mountainous regions, like the Alps and Himalayas, its full force is felt on every precipice and exposed rock surface. In mountain regions, where glacier and avalanche accumulate, these, after grinding and wearing, discharge their disintegrated rock debris into the glens and valleys below; while along arctic shores they launch the iceberg and ice-floe, which float the debris into mid-ocean, and drop it on the sea-bed as they melt away. Besides winds, rains, and frosts, the carbonic acid and moisture of the atmosphere also exert a weathering and wasting influence on every exposed rock-surface—most perceptibly, of course, on soft and calcareous substances, (Lat., *calx*, *calcis*, lime,) but less or more on every other material.

The Aqueous agents, or those operating through and by the power of moving water, are chiefly streams and rivers, waves, tides, and ocean-currents. All running water exerts a wearing influence on the surfaces over which it flows, partly from its own force and partly also from the rubbing or triturating of the pebbles and stones it carries along with it. In this way, all streams excavate for themselves a channel; and the deepening and shifting of such channels produce, in course of time, ravines and gorges. As with streams, so with the larger rivers—their excavating power depending partly on their velocity, partly on

their volume of water, and partly on the nature of the material (soft or hard) over which they flow. As the higher ravines and gorges have been excavated by streams and mountain-torrents, so the lower valleys (*valleys of erosion*) have been eroded or worn out by rivers—the eroded material being carried onward, and deposited as silt and sediment in lakes, estuaries, and seas, there to form the strata of future formations. Among the most powerful and persistent of aqueous agents, are the waves, tides, and currents of the ocean. The waves battering against the sea-cliffs are continually abrading and undermining, and this in proportion to their own force, the structure of the cliffs, and the softness of the material upon which they act. The materials of the landslips and cliff-falls thus occasioned, pounding against each other under the commotion of the waves, are soon reduced to shingle, and sand, and mud, and in this state are swept along by the tides, and deposited in the quieter recesses of bays and gulfs. We have abundant evidence of this action along our own coasts, wherever the cliffs consist of the softer stratified rocks; and taking into account the length of shore-line all over the world, we can readily conceive the enormous amount of waste and re-distribution of material that annually takes place through the medium of wave and tidal action. As with tidal currents, so also with the great oceanic currents, (the Equatorial, Polar, Gulf Stream, &c.,) though in a less obvious manner. They are all abrading and transporting rock-matter from one area to another, and distributing it along the sea-bottom in stratiform masses of great extent, and, it may be, in many instances, of great thickness and variety.

The main effect of aqueous action, whether it manifests itself in rain, rivers, waves, tides, or oceanic currents, is to wear down the high and exposed portions of the earth's crust, and transport the abraded material to lower levels. The matter worn from the hills and high-lands by frost, and rain, and rivers, is borne down to lakes, and estuaries, and seas, there to be spread out as sedimentary strata; and that wasted from the shores by waves, or scoured from the sea-bed by currents, is in like manner distri-

buted in the more sheltered bays and recesses, or carried out to the quieter depths of the ocean. Aqueous agency is thus the great wearer and smoother-down of all the irregularities and asperities of the dry-land; just as it is the great former of all the sedimentary and stratified rock-matter which fills up the hollows and inequalities of the ocean.

The Organic agencies are those, of course, which arise from the growth and decay of vegetable and animal life. The vegetable matter that accumulates year after year in peat-mosses, like those of our own islands; in cypress-swamps, like those of North America; and in mangrove jungles, like those of many tropical estuaries, are illustrations of the mode in which plant life adds to the solid material of the globe. Many of these accumulations are of great thickness and extent; and if overlaid by other rock-matter, and sufficiently consolidated, would form beds of lignite or wood-coal, (Lat., *lignum*, wood,) precisely similar to that excavated from the clays and gravels of many countries; or if still further consolidated and mineralised, would be converted into true coals like those of the older strata. Besides accumulating *in situ* (their original position) as peat-mosses, cypress-swamps, jungle, and forest-growths, vegetable matter is also drifted down in masses by many rivers (as the pine-rafts of the Mississippi,) where getting water-logged, it sinks among the sediments of their estuaries, and adds, of course, to the accumulation. As with plants, so with animals. The larger and terrestrial animals add little to the solid framework of the globe, and when entombed in sediments, only become evidences of the kind of life that existed at the period of their enclosure; but the minute and marine animals, as shell-fish, corals, foraminifera, and other microscopic creatures, contribute largely by their secretions to the amount of its rock matter. Shell-beds, whether entombed where the animals lived, or drifted on shore, form beds of shelly limestone; coral-zoophytes pile up reefs and barriers of vast dimensions in the oceans of the southern hemisphere; and the minute shields and cases of the foraminifera (microscopic organisms dotted with

pores or *foramina* for the protrusion of their parts) accumulate in myriads on certain portions of the sea-bed, where in process of time they will constitute calcareous strata of great extent and thickness. Many of the chalks and limestones and marbles in the solid crust are but the shell-beds, coral-reefs, and foraminiferal accumulations of former epochs; and we perceive in those now accumulating in existing seas, the chalks and limestones of future ages.

The Chemical agencies, though less perceptible, perhaps, than either the atmospheric, aqueous, or organic, are nevertheless effecting important changes on and within the crust of the earth. As the carbonic acid and moisture of the atmosphere *weather* and dissolve the surface of calcareous rocks, so, in the solid crust, the percolation of water containing carbonic acid, of water and steam heated to high temperatures, and of hot vapours and gases in general, dissolves the rocky strata, and carries the matter in solution to the surface. This is the origin of our chalybeate or iron springs, of our calcareous or lime springs, siliceous or flint springs, (Lat., *silex*, flint,) salt springs, boràx springs, sulphur discharges, and the like, which occur less or more in every region; but notably so in the neighbourhood of volcanoes and earthquake districts. There is thus a twofold effect produced by these agencies—a wearing of material from within the crust, and a re-deposition of it on the surface in the form of lime, silex, salt, sulphur, and other similarly formed substances. Besides such results as the above, there are also the incessant actions and reactions that take place between all mineral bodies, as in the solidification of strata, the production and cooling of volcanic discharges, the formation of mineral and metallic veins, and the like —all of which involve the consideration of chemical agency at one period or other of their formation.

Igneous or Vulcanic agency (Vulcan, the god of fire) exhibits itself most perceptibly in volcanic eruptions and discharges, in earthquakes, hot springs, gaseous exhalations, and the like—all of which obviously depend on the presence of heat more or less deeply seated in the crust of

the earth. The true volcano acts partly by upheaving the rocks through which it bursts, but mainly and most frequently by the accumulation of the erupted materials round its crater or bowl-shăped orifice, (Gr., *crater*, a bowl.) These materials—dust, scoriæ or cindery fragments, loose stones, and lava or molten rock-matter—accumulate in a conical form round the crater, and in course of ages pile up mountains many thousand feet in height. As discharge after discharge increases the volcanic cone, so volcanoes occurring less or more in linear directions, constitute mountain-chains. Closely associated with volcanoes, and occurring most frequently immediately before their eruptions, are earthquakes, whose convulsive throes disrupt the solid crust—causing rents and fissures, upheaving one portion and sinking another, and everywhere producing irregularity of surface. Hot springs, gaseous exhalations, and kindred phenomena, may and do occur in almost every country; but most abundantly, and on a notable scale, in volcanic and earthquake areas. Besides the volcano and earthquake, which accumulate, upheave, submerge, and disrupt more or less suddenly, there is also a slow and gradual uprise and downfall of the earth's crust in certain areas, which in all likelihood is dependent on the same great source of vulcanism or internal heat. The coasts of Scandinavia, Spitzbergen, Siberia, and the islands of Arctic America, are all marked by terraces or recent shore-lines of uprise; just as portions of Greenland, the southern shores of the United States, and the coasts of Cutch in India, are marked by evidences of gradual depression. This slow but incessant *crust motion* is evidently the great re-distributor of sea and land, though its action is too often overlooked in our study of minor, but more obvious phenomena.

The main effects of volcanic or igneous agency is to upheave or submerge, to disrupt and accumulate, to disturb the original horizontal position of the stratified deposits by fractures and upthrows and downthrows; and everywhere to produce a set of rocks altogether unlike those sedimented in layers from water. In most instances the igneous rocks are hard and crystalline, and

massive or amorphous in structure, (Gr., *a*, without, *morphè*, definite form); and even where the successive discharges of lava, dust, and ashes are accumulated one above another in a volcanic mountain, this arrangement can never be mistaken for that of sedimentary stratification. Even where showers of dust and ashes happen to fall in water, and become interstratified with true sediment, their texture is in general easily distinguished from that produced by the water-worn particles of the aqueous strata. A common effect of the igneous rocks is to harden and alter the texture of the stratified rocks with which they come in contact, and this whether they flow over them in beds of molten lava, or burst through them, and fill up rents and fissures.

Such are the agents—atmospheric, aqueous, organic, chemical, and igneous—which are at present productive of all geological change on and within the crust of the globe, and which, we infer from the character of the stratified and unstratified rocks, have been productive in like manner of all the phenomena that took place in former ages. Believing in the uniformity of natural law, the geologist ascribes similar results to similar causes; and thus his knowledge of existing operations becomes the key wherewith to unlock the secrets of the past. In investigating the earth's crust, he finds strata composed of certain ingredients laid down in a certain way, containing the remains of certain plants and animals, occupying definite areas, and upturned and broken through in a peculiar manner by unstratified rocks; and he tries, from his knowledge of what is now taking place on the earth, to account for these phenomena—the agents which produced the materials of the strata, the nature and extent of the waters in which they were deposited, the kind of life that peopled these waters and adjacent lands, and,

lastly, the amount of change produced on the district by volcanic discharges and earthquake convulsions. To all this he has no other guide than his knowledge of the causes that are now productive of geological change, and which we have endeavoured briefly to explain in the preceding pages.

Though usually described as meteoric, aqueous, organic, chemical, and igneous, these modifying causes may, on the whole, be conveniently considered under two great categories—the powers of waste and levelling from without, and the powers of reconstruction and upheaval from within. Uncontrolled, the meteoric and aqueous would, in course of ages, reduce all the high and dry lands to a uniform surface of watery level, incompatible with that diversity of vegetable and animal life which seems to be the grand design of creation; but to counteract this tendency, the vulcanic forces, upheaving from within, produce irregularity and diversity of surface—deep sea and dry land, hill and dale, level plain and rugged mountain, and all that variety of condition on which variety of plant life and variety of animal life is so immediately dependent. Between these two great opposing forces the earth's crust is ever held in habitable equilibrium. Let us next consider its structure and composition as the results of their incessant operations.

III.

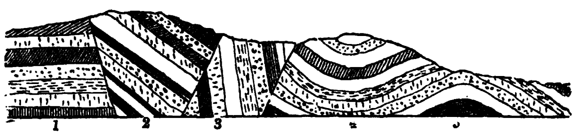
THE ROCKY CRUST—ITS COMPOSITION AND STRUCTURAL ARRANGEMENT.

The result of the operations described in the preceding chapter is the production of rocks and rock-formations. Rains and rivers cannot wear and waste without producing sediments in the waters into which they flow; volcanoes cannot emit showers of dust and ashes, or overflows of lava, without creating new rock-masses. The older rocks will thus get covered over by the newer; and in course of ages there will necessarily be a vast succession of stratified and unstratified formations. It is this vast succession of water-formed, organically-formed, chemically-formed, and fire-formed rocks which constitutes the exterior portion of the globe; and this we designate the "crust," in contradistinction to the "interior," of which we know nothing by direct observation.

That the interior differs from the crust, if not in the nature of its substances, at all events in the condition in which they exist, is evident from two main considerations. In the *first* place, the weight of the whole globe, as deduced from astronomical and physical considerations, is $5\frac{1}{2}$ times that of water, while the average weight of the known rocks is only $2\frac{1}{2}$ that of water. If the laws of attraction and gravitation hold good, the rocks known near the surface would, at the depth of 100 miles, be so compressed as to give to them a much greater density or weight than $5\frac{1}{2}$ times that of water; so that if the interior of the earth be composed of rock-matter, it must be in a lighter and more diffused state than that in which it appears at the surface. In the *second* place, it has been found

by experiments that while the first 80 or 90 feet of the crust becomes warmer under summer's heat and colder under winter's cold, all beneath that depth grows hotter and hotter, at the rate of one degree Fahr. for every 60 feet of descent. If this ratio holds good, no matter what the effects of compression, a temperature must be reached, in less than 100 miles, at which every rock-substance known at the surface would be held in a state of molten fusion, and from such a source in all likelihood arises the phenomena of earthquakes and volcanoes. These two considerations, altogether different in their nature, tending so remarkably to the same conclusion of a lighter and more rarefied interior, and heat being the only known agent capable of producing such a condition, it has become a very prevalent belief that the interior of the earth is in a state of high incandescence or molten fusion. But whatever the condition of the interior, it is advantageous to draw a line of distinction between the exterior crust, whose formation we can discover, and the interior mass, of which we can know nothing by direct observation. In this crust all geological change is registered; and to the interpretation of this record, by sound methods of induction, do the students of modern geology very wisely restrict their investigations.

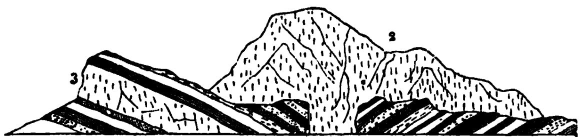
This crust, as already stated, is mainly composed of stratified and unstratified rocks—the former for the most part produced by deposition in water, hence known as *aqueous*, *sedimentary*, or *stratified*; and the latter chiefly discharged from volcanic orifices, and on that account termed *igneous*, *eruptive*, or *unstratified*. The original disposition of sedimentary rocks is less or more horizontal; but when



1. Horizontal strata; 2. Inclined; 3. On edge; 4. Synclinal; 5. Anticlinal.

broken up by earthquakes and volcanoes, they assume every conceivable position, being thrown up at various

inclinations, bent, contorted, or even sometimes overturned upon themselves. Such positions are technically known as *horizontal*, *inclined*, *vertical* or *on edge*, bent into *anticlines* and *synclines*, *contorted* and *reversed*. The igneous rocks, on the other hand, which are the main agents in disturbing the sedimentary strata, are usually spoken of as disrupting, overlying, and interstratified—*disrupting*, when they simply break through the strata; *overlying*, when they have flowed over them like sheets of lava; and *interstratified*, when the overflow has been covered over by newer sediments, and appears

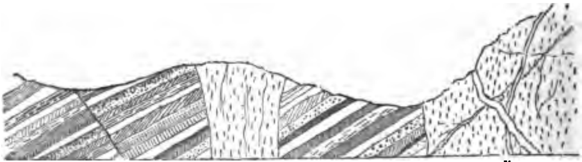


1. Disrupting; 2. Overlying; 3. Interstratified.

among them as a stratum, or when showers of dust and scoriæ have fallen in water, and been overlaid by true water-formed sediments.

When strata have been disturbed from their original horizontal position, they necessarily slope or incline downwards into the crust, and this slope is technically known as their *dip*. The broken edge of the stratum that comes to the surface is called the *outcrop*, and the line of outcrop is spoken of as the *strike*. The dip and strike of a stratum are necessarily at right angles to each other—a southerly dip having an east and west strike, and *vice versa*. As solid strata cannot be acted upon by subterranean forces without being rent and fractured, the direction, slope, and character of such fissures assume importance in geology, and are spoken of as *faults*, and as *upthrows* or *downthrows*, according as the strata rise or fall from the position of the observer. When a fault or fissure is filled up with igneous matter from below, the injected rock is termed a *dyke;* and when fissures are occupied by aggregations of mineral and metallic matter, they are spoken of as *lodes* and *veins*. Besides the greater faults and fissures,

which often extend for miles without change of direction, there are minor rents, which are simply called *cracks*, when



1. Fault; 2. Dyke; 3. Lode and Veins.

varying and irregular; but *joints*, when they divide the strata, more or less regularly, into blocks with parallel faces.

The *structure* of rocks—that is, the mode in which they are piled up in the crust—and their *texture*—that is, the internal arrangement of their component particles—often afford important indications of the conditions under which they were formed, and hence the necessity of explaining the technicalities by which these are distinguished. In describing the stratified rocks, we use the term *stratum* when of some thickness, and *layer* when thinner; and though in familiar language we speak of *beds* of sandstone and *seams* of coal, yet, in strict phraseology, *bedding* is the manner in which strata overlie one another, and *seam* the parting or line of deposit between them. Strata which separate in thin layers are said to be *flaggy*, as our paving or flagstones; and *laminated*, when in still thinner leaves or plates—these laminæ indicating tranquillity or slowness of deposition. Another structure frequent in fine-grained strata, like clay-slate or roofing-slate, is that of *cleavage*, which causes the rock to split in thin plates, (slaty-cleavage,) and this not in lines parallel to, but more or less perpendicularly through, the stratum. Where the lines of stratification are obscure, as among the old crystalline and micaceous rocks of the Highlands, the strata are spoken of as *schists*, (Gr., *schisma*, a splitting); and their irregular lamination as *foliation*, (Lat., *folium*, a leaf); and hence, also, the terms *foliated* and *schistose*, which are generally applied to them. Among the igneous rocks we have the *columnar* structure, so beautifully exhibited in

the basalts of Staffa and the Giant's Causeway; the *sub-columnar*, or less perfectly columnar, as in many greenstones; the *tabular*, or square-like blocks, so common among granites; and the *concretionary* or *spheroidal*, which is best shewn on the weathering of basalts and greenstones.

As regards *texture*, the terms used to describe it are, for the most part, the same as those employed in every-day language. Thus a rock is said to be *porous* when spongy-like, or full of pores, like pumice; *vesicular*, or full of little cavities, like lava; *fibrous*, when composed of distinct fibres, like asbestos; *granular*, when made of distinct angular grains or particles; and *oolitic*, (an oolite or roe-stone,) when it consists of rounded grains, like the roe of a fish. Again, rock-substances are spoken of as *crystallised*, when consisting of distinct crystals; *crystalline*, where the crystallisation is confused and indistinct; *sub-crystalline*, where the texture is still less crystalline and obscure; and *saccharoid*, when it assumes, like certain marbles, the appearance of loaf-sugar. Such terms as *earthy*, *friable*, *compact*, &c., need no explanation; they are understood in scientific descriptions in the same sense as in every-day language. *Sandstones* are but consolidated sands; *conglomerates*, consolidated gravels; *breccias*, or rocks of *brecciated* texture, are composed of angular fragments, and not of water-worn pebbles, as in the case of conglomerates; and *shales*, (Ger., *schalen*,) but consolidated muds, which have assumed a more or less laminated structure through pressure, and split up in irregular leaves or laminæ.

Whatever be the composition, structure, or texture of rocks,—that is, whatever the chemical substances of which they consist, (silica, alumina, lime, magnesia, &c.,) the manner in which they are piled up in the crust, or the more intimate arrangement of their particles,—Geology has mainly to do with them as stratified and unstratified masses. The igneous may afford evidence of the convulsions to which the earth's crust has been repeatedly subjected; but the stratified, having been brought together by water, deposited in water, and containing the remains of plants and animals, are those to which we

chiefly turn for evidence of the earth's former conditions. They constitute, as it were, the great chapters of world-history; and Geology endeavours to arrange them in chronological order, that it may trace in natural sequence the course of events from the earliest to the latest periods. To this end it is chiefly guided by the facts that the oldest rocks are necessarily the deepest seated, that the older deposits are generally more compacted and altered in character than the recent, and that the more ancient the fossil plants and animals, the more widely do they differ from those now existing. In this endeavour, it arranges the strata into groups, and series, and formations—each formation consisting of the sediments that were deposited continuously in any lake, estuary, or branch of the ocean. Under the operation of aqueous and igneous forces, sea and land must have frequently changed places—the dry land becoming the sea-bed, and the sea-bed the surface of the dry land. At every such change the upheaved sediments constitute a *formation*, and contain evidence in their materials of the causes that produced them, and in their fossils of the kind of life that peopled them and the surrounding dry lands. Thus, were the sands and clays, and muds and vegetable debris which form the low shifting delta of the Mississippi to be converted into dry land, they would constitute an *estuarine formation*, and furnish evidence, not only of the life that peopled the Gulf of Mexico, but also of that (vegetable and animal) which inhabited the continent of America, and which had been drifted down by the current of the river. In the same way we have *marine formations*, and *lacustrine* or *lake formations;* and we arrive at a knowledge of their areas, their origin, the plants and animals that lived in and around them, and the conditions under which these existed, by mapping out the strata, examining their structure and composition, and deciphering the fossils they contain.

As with formations now accumulating, so with those that occur deep-seated in the crust of the earth. Geology endeavours not only to read them individually, but to arrange them in chronological order, so as to produce a

connected and intelligible history of the globe. As the historian speaks of reigns and dynasties and centuries, so the geologist speaks of series and formations and epochs; and as the historian groups his centuries into Ancient, Mediæval, and Modern history, so the geologist groups his epochs into Primary, Secondary, and Tertiary; or, referring to their fossils, into Palæozoic, (Ancient Life,) Mesozoic, (Middle Life,) and Cainozoic (Recent Life.) Taking the formations of the British Islands, and arranging them in sequence, from the youngest to the oldest, we have—(1.) superficial accumulations, as soil, the silts of lakes and rivers, peat-mosses, and the like, and these constitute the *Recent* or *Quaternary System;* (2.) beneath these lie such deposits as the stratified clays, sands, and gravels of the London basin, which form the *Tertiary System;* (3.) immediately beneath the London strata lie the chalks and greensands of Kent and Surrey, and these constitute the *Cretaceous* or *Chalk System;* (4.) under the greensands occur the clays and sandstones of the Sussex wolds, the oolites of Portland and Bath, and the Lias clays and limestones of Yorkshire, and these formations compose the *Oolitic System;* (5.) beneath the oolites lie the red sandstones and marls of Cheshire, which constitute the Upper New Red Sandstone or *Triassic System;* (6.) under the Trias lie the red sandstones and magnesian limestones of Durham, forming the Lower New Red Sandstone or *Permian System;* (7.) beneath the Permian spread out the limestones, sandstones, ironstones, and coals of Northumberland, &c., known as the *Carboniferous System;* (8.) beneath the coal-measures occur the red sandstones, marls, and limestones of the *Old Red Sandstone* or *Devonian System;* (9.) under these lie the limestones, sandstones, and slates of the *Silurian* and *Cambrian Systems,* so characteristic of portions of Wales; and (10.) under these, again, rest all the crystalline and slaty rocks of the Scottish Highlands, for instance, in which stratification is indistinct, and which contain no traces of fossils, and hence termed the *Metamorphic* or *Non-fossiliferous System.* Arranging these in tabular form, we have the subjoined intelligible synopsis:—

TABULAR VIEW OF STRATIFIED SYSTEMS.

RECENT or QUATERNARY, ... TERTIARY, ...	CAINOZOIC. (*Recent-Life.*)
CRETACEOUS or CHALK, ... OOLITIC or JURASSIC, ... TRIASSIC—UPPER NEW RED, ...	MESOZOIC. (*Middle-Life.*)
PERMIAN—LOWER NEW RED, ... CARBONIFEROUS or COAL-BEARING, ... OLD RED SANDSTONE or DEVONIAN, ... SILURIAN and CAMBRIAN, ...	PALÆOZOIC. (*Ancient-Life.*)
METAMORPHIC, ...	HYPOZOIC. (*Under-Life.*)

As the stratified have been arranged in chronological order, so we attempt a similar arrangement of the unstratified, though from the eruptive nature of these rocks, which break indiscriminately through strata of all ages, it is impossible to arrive at the same sequential precision. It is usual, however, to designate those which occur in connexion with tertiary and quaternary strata as *Volcanic;* those chiefly associated with the secondary and upper palæozoic systems as *Trappean;* and those found more intimately intermingled with metamorphic and primary strata as *Granitic.* It is true that volcanic outbursts may happen in granitic districts, just as granites are found associated with secondary strata; but as a provisional and convenient distinction, the terms Volcanic, Trappean, and Granitic are employed by all working geologists. The first refers to the lava and scoriaceous-like aspect which characterises the products of active volcanoes; the second to the terraciform features (Swedish, *trappa*, a stair) of the hills mainly composed of basalts, greenstones, and similar igneous rocks; and the last to the granular texture of the true and typical granite, which forms by far the largest proportion of the primary unstratified compounds.

Such is a rapid outline of the composition and structural arrangement of the earth's crust. Of the sixty-four or sixty-five elements into which chemists have resolved all the substances of the globe, only a very few enter largely into the composition of the rocks with which Geology has to deal. The compounds of silica, alumina, lime, magnesia, carbon, &c., the ores of the metals, and water, are the bulkier ingredients—their combinations into crystals, minerals, and ores being, however, more the subject of Mineralogy than of Geology, which has mainly to consider their aggregation into *rocks*, and the causes concerned in this aggregation. Restricting themselves to this consideration, geologists find that the crust consists in the main of *stratified* and *unstratified* rocks —the former the products of water-agency, and deposited in layers more or less horizontal; the latter the products of fire, and breaking through and disturbing the former from their original horizontal positions. In this way technicalities are required to describe these *positions*, be they inclined, bent, contorted, on edge, or reversed; or be they fissured and faulted, separated by dykes, or intersected by lodes and veins. To render description more intelligible, the *structure* of the stratified rocks is spoken of as jointed, as flaggy, fissile, laminated, shaly, slaty, schistose, and foliated, as the case may be; while the unstratified are either columnar, sub-columnar, tabular, massive, or amorphous. The *texture* or intimate composition of rocks often throws light on the manner in which they have been aggregated, and this is usually described by such terms as compact, porous, vesicular, cellular, fibrous, saccharoid, crystalline, sub-crystalline, granular, brecciated, conglomerate, and the like, all familiar in every-day language, and of easy comprehension. The great object of Geology, however, is to arrange the rocks so described into groups and *formations*—each formation being the sediments of a certain sea, lake, or estuary; and these formations, again, into chronological order, that we may be enabled to read in sequence the history of the earth's mutations from the earliest period recorded in the crust, down to the current epoch. For this purpose the

formations are grouped into *systems*, and these again into greater periods, according to the aspect of their fossils; and in this way the geologist deals with world-history as the historian deals with human-history. He describes the reigns of certain forms of life and the external conditions under which they flourished, just as the latter describes the reigns of kings and dynasties and nations, and the manners of their times; and grouping them into major life-cycles, he speaks of palæozoic and mesozoic and cainozoic forms and periods, in the same way as the historian speaks of ancient, mediæval, and modern.

IV.

THE IGNEOUS OR FIRE-FORMED ROCKS.

BEFORE describing the stratified systems, which form the great record of the world's history, it may be convenient to consider the igneous rocks—their distribution, characteristics, and relations to the strata with which they are associated. As already mentioned, it is usual to arrange the pyrogenous or fire-formed rocks (Gr. *pyr*, fire, *ginomai*, I am formed) into Volcanic, Trappean, and Granitic, not that there is any difference in their mode of formation, but that their relative ages have impressed different mineralogical characters upon them, and because they are in the main respectively associated with different stratified systems.

VOLCANIC.

Under this head we comprise all igneous products which have been ejected from volcanoes since the commencement of the Tertiary period. Of these volcanoes many have long since become *extinct*, like those of Auvergne and the Rhine: some seem merely *dormant*, and may or may not again burst forth into activity; while others are incessantly *active*, emitting vapours, discharging showers of dust and ashes, or pouring forth floods of molten lava. Whatever be their condition, their principal rock-products are *dust*, *scoriæ* or cindery matter, *sulphurous muds*, *lapilli* and *volcanic-bombs*, *pumice* or lava-scum, and *lava* itself in every degree of fusion. As a rock, lava assumes many different characters, according to the manner and rapidity of cooling—becoming under rapid refrigeration a glassy obsidian, or under slower processes a

basalt, a granular trachyte, or a cellular tufa. Pressure has also much to do with the character of the resultant rock, a lava cooled under the open air (sub-aërial) being different in aspect from one discharged under water, (sub-aqueous,) or at great depths in the crust of the earth. Dust and scoriæ overlaid by lava on the slopes of a volcano will differ also in lithological (Gr. *lithos*, a stone, stony) character from those that happen to fall in water and become imbedded among aqueous sediments. In this way volcanic products, though differing very little at first in mineral composition, assume in the long run a great variety of rock-characters, according as they are sub-aërial or sub-aqueous, rapidly or slowly cooled, and according to metamorphism or internal changes that may arise from long-continued pressure or chemical reassortment of their component ingredients.

Though *disrupting* or breaking through strata of all ages, volcanic rocks are chiefly associated, as *overlying* and *interstratified* masses, with tertiary and recent formations. In this way they have modified, and are still materially modifying the crust of the globe, partly by their rock-accumulations, and partly by the earthquake-convulsions that accompany their manifestations. They occur in connexion with tertiary strata in various parts of Europe, Asia, Australia, New Zealand, and South America; and at present upwards of three hundred known craters are actively discharging their products in lines and centres, over which more than double that number are now dormant, or only manifest symptoms (in hot-springs, mud-springs, and heated vapours) of expiring activity. In Europe the principal centres are those of the upper Mediterranean, with Etna, Vesuvius, &c.; the Azores, far off in the Atlantic; and Iceland, with Hecla and several other unvisited craters. In Asia vulcanism manifests itself in the region of the Red Sea, Levant, and Caspian, and in the central high lands; but intensely, and on a grand scale, along the whole of the Pacific boundary, from the Indian Archipelago on the south, through the Philippine Islands, the Japan Islands, the Kurile Islands, and the peninsula of Kamtchatka, on the north. In

Africa the great unknown interior is apparently undisturbed; but along the Red Sea border, in the Indian Ocean, (Bourbon and the Mauritius,) and along the Atlantic boundary, (Ascension, Cape Verde, and the Canary Isles,) there are abundant evidences of recent and existing vulcanism. In the American continent, the whole chain of the Andes, from Tierra del Fuego on the south, through Chili, Bolivia, and Columbia, in the north, may be said to be one unbroken line of volcanic activity, which is continued throughout the West India Islands on the one hand, and through Central America and Mexico on the other, northward more or less through the Rocky Mountains and the Aleutian Islands. Indeed, the whole terrestrial boundary of the Pacific, both on the American and the Asiatic side, is one vast cincture of volcanic action, which is manifested also less or more over its entire area in the Sandwich, Marquesas, Galapagos, Society, Friendly, New Zealand, and other islands.

Wherever these volcanoes occur, whether in long linear directions like the Andes, or in widely-separated centres like the islands of the Pacific, they are always less or more accompanied by earthquake convulsions; and thus we have not only the accumulation of rock-matter in hills and mountain-chains, but upheavals and sinkings of the surrounding country, rents and fissures of the crust, and the filling of these, in many instances, with injections of molten lava from below. In fine, by a careful study of existing vulcanism, the nature of the products ejected, the effect of rapid or slow cooling upon these products, the effects also produced by pressure,—that is, whether they have been formed under the open air or in the depths of the ocean,—and the results of earthquake convulsions, we are enabled to arrive at a clearer conception of the phenomena arising from igneous activity in former ages. The annexed illustration presents, in the foreground, an ideal section of a volcano with its central and lateral craters, and vast accumulations of lava and scoriæ piled up in irregular succession; and in the distance, the usual conical aspect of an active volcanic mountain. From the mode and rate of accumulation in known volcanoes,

it will be readily perceived that the elaboration of mountains and mountain-chains must be the work of ages, and that, when studied in this light, they become in some degree a measure of geological chronology, and proofs of the vast antiquity of our planet. In a geographical point of view, the aspect of volcanic districts is necessarily hilly

Ideal section of Volcano, with central and lateral Craters. Conical aspect of Volcanic Mountain.

and irregular. Hills more or less conical and crateriform, with narrow winding valleys between, are the common features—the hill-sides regularly sloping, and barren of vegetation where the volcanoes are still active; but scarped, cliffy, and partially clad with shrubs and trees, where, of ancient date, worn down by meteoric action, and free from the scorching effects of recent discharges.

Trappean.

Under this division geologists usually comprehend all those igneous products which have been produced during the deposition of the mesozoic and palæozoic strata. In Britain they are largely associated with the Old Red Sandstone and Coal-Measures, in the character of basalts, greenstones, whinstones, felstones, pitchstones, porphyries, amygdaloids, and traptuffs, either as disrupting, overlying, or interstratified masses. Whether we look upon them as eruptive products forming hills, as sheet-like overflows covering over or intermingled with true sediments, or as dykes filling up fissures that traverse the stratified rocks, we find in all of them the exact analogues of the volcanic

series, and so similar in many instances that it would be impossible to distinguish between them but for the strata with which they are associated. As highly-heated products, they harden and alter the strata with which they come in contact—converting sandstones into quartzites, shales into jaspers and porcellanite, and bituminous coals into coke-like anthracites. In the *basalts*, which are usually of a dark colour, close-grained in texture, and frequently columnar in structure, we perceive the effects of rapid cooling, or cooling under considerable pressure. In the *greenstones*, which are opener in texture and more distinctly crystalline, and merely massive or but subcolumnar in structure, we have evidently the results of slower cooling; while in *pitchstones* and *felstones*, which are homogeneous and compact, we have more the results of differences in original composition, and perhaps to some extent of differences in degrees of fusion. In the *porphyries*, (Gr. *porphyreos*, purple-coloured, so called from a reddish coloured variety largely used in ancient Egypt,) which are but felstones with larger interspersed crystals of felspar or quartz, we have, perhaps, the results of metamorphism, or changes subsequent to cooling; and in the *amygdaloids* (Gr. *amygdalon*, an almond) we are presented with the original almond-shaped cavities of the vesicular lava filled up with infiltrations of calcareous spar, rock-crystal, agate, jasper, and similar crystalline minerals. In the *tuffs* or *tufas*, which are always of an earthy and softer texture than any other of the trap-rocks, we have clearly the consolidated muds, dusts, and ashes of the period—some consolidated by the pressure of superincumbent beds on land, and others by having fallen as sedimentary matter in water. Whatever name they are known by, they are but the erupted products of former volcanoes, rendered more compact and crystalline by that slow process of internal change or *metamorphism* to which every substance in the earth's crust is incessantly subjected.

Trap-rocks occur in all countries in connexion with the secondary and palæozoic strata, and not unfrequently with the still older metamorphic and granitic series,

which they cut through by dykes of basalt, greenstone, and porphyry. In Scotland they enter largely into the composition of the Sidlaw, Ochil, Campsie, Kilpatrick, Kilbarchan, Pentland, and other hill-ranges; in England they are found in the Cheviot, Cumberland, Welsh, and Derbyshire hills; and in Ireland in the hills of Antrim, Londonderry, and Armagh. Their usual aspect is rounded or terraciform hills, with frequent cliffs of basalt and greenstone; but it should always be borne in mind that what is now preserved of these ancient igneous accumulations is but the merest nucleus—all the higher portions, as well as all the softer and looser compounds, having been washed away by subsequent denudation. It is greatly to this denudation that trap-hills owe their terraced aspect, the softer tufas and interstratified sediments yielding to the waste, while the harder beds of greenstone and basalt have resisted, and now stand out in cliffs and terraces. The disintegration of trap-rocks, rich in lime, potash, and soda, produce open, friable, and fertile soils, the value of which is further increased by the natural drainage they receive through the joints and fissures of the underlying rocks.

Granitic.

As already explained, the granitic series comprehends all those highly crystalline rocks which, like granite, syenite, and porphyry, are mainly associated with the older palæozoic and metamorphic strata. Whether it arises from their having been formed at greater depths, and consequently subjected to greater pressure, or from internal or metamorphic changes that have taken place subsequent to their formation, their crystalline texture is certainly more distinct than that of the trap-rocks; they also shew less structural arrangement, and are never porous or vesicular, like any of the lavas. They are massive or tabular rocks, with distinct crystallisation, and altogether wanting in that alternation of softer and harder parts which characterise both the trappean and volcanic series. Looking at their homogeneous texture,

the distinctness of their crystalline aggregation, and other peculiarities, the least practised eye will at once perceive a vast difference between them and the younger trappean and volcanic rocks. They are, in fine, eminently *plutonic*, (*Pluto*, god of the lower regions,) that is, have been formed at great depths;—while the traps and lavas, on the other hand, are as eminently *volcanic*—that is, produced at small depths, or absolutely on the surface.

The typical *granite*, so called from its granular aspect, and used so largely for industrial purposes, is a compound of felspar, quartz, and mica—the crystals in some varieties being small and closely compacted, and in others so large and loosely aggregated as to be readily separable. What is termed *syenite* (from Syene, in Upper Egypt, where it was early worked) is a compound of felspar, quartz, and hornblende; *protogine*, a compound of felspar, quartz, and talc; *eurite*, a whitish, fine-grained mixture of felspar and quartz; *hypersthenic granite*, a compound of felspar, quartz, and hypersthene, with scattered crystals of mica; and *porphyritic granite*, any granite that has disseminated through its mass large and independent crystals of felspar. The granites of Aberdeen, Argyle, Devon and Cornwall, the Mourne and Wicklow mountains, &c., are now well-known and largely-used rocks, differing in colour, compactness, and durability. Where only two ingredients (as felspar and quartz) enter into the composition, the rock is spoken of as a *binary* granite; where three (as felspar, quartz, and mica,) a *ternary* granite; where four, a *quaternary;* and so on where the component crystals are still more numerous. To these and many other similar rocks the term *granitic* is applied, as indicating their nature and affinity; and in all of them felspar, quartz, mica, hornblende, and hypersthene are the principal ingredients; and talc, steatite or soapstone, chlorite, and schorl or tourmaline, the accidental or modifying minerals.

Granitic compounds—that is, true granites, syenites, protogines, porphyries, steatites, serpentines, and the like—occur, in eruptive masses, dykes, and veins, in all the higher and older mountain-ranges of the world. They appear largely and in great variety in the Grampians and

Highlands of Scotland; in the Cumberland and Cornish mountains in England; in the Mourne and Wicklow mountains in Ireland; in the Pyrenees and Alps; in the Scandinavian and Oural ranges; in the Himalayan and Central chains of Asia; in Australia and New Zealand; in the Abyssinian and Central ranges of Africa; and flanking, more or less, from end to end the giant ranges of the Andes and Rocky Mountains in the American continent. In fine, they are to the older mountain-axes what the traps are to those of the secondary period, or the volcanic to the hills of the tertiary and current epochs.

Such are the igneous or fire-formed rocks—their mineral characters, their modes of occurrence, and the effects they produce on the strata with which they are associated, as disrupting, overlying, or interstratified masses. Though arranged for the sake of convenience into Volcanic, Trappean, and Granitic, they are greatly alike in chemical composition; their present mineralogical aspects depending partly on the state of fusion in which they are erupted, partly on their slow or rapid cooling, and whether this took place under pressure or in the open air, and partly on the internal or metamorphic changes to which they have been subsequently subjected. As groups, the older and deeper-seated Granites are the most massive, homogeneous, and crystalline; the Traps display more frequently structural arrangements, are less crystalline, and exhibit in their partially-filled cavities and tufaceous beds clearer evidences of their igneous origin; while the Volcanic, being more recent and still in course of formation, are more vesicular and scoriaceous, as well as more varied in their mineral character, and from their obvious relations, become the key to the interpretation of the Trappean and Granitic. Whatever their age or mineral character, they all act in a similar way on the sedimentary

systems—disrupting their strata, and throwing them up or down at various angles of inclination; filling their fissures with dykes and veins; overlying them in sheet-like flows; getting overlaid by new sediments, and becoming interstratified; and in every case acting as heated masses in altering the texture of the beds with which they come in contact. Theoretically, they are of vast importance to the geologist in enabling him to interpret the changes to which the earth's crust has been subjected; economically, they yield many products of utility and ornament. The granites, basalts, and greenstones are amongst the most durable of rocks for sculpture, building, and road-making; certain serpentines, amygdaloids, and lavas are used as ornamental stones; rock-crystals, tourmalines, almandines, agates, jaspers, carnelians, calcedonies, and other gems, are derived from one or other of the groups; and kaolin or China-clay, obsidian, pumice, pozzuolana, sulphur, borax, &c., are also among their well-known and familiarly-used products.

V.

LOWER PALÆOZOIC SYSTEMS: METAMORPHIC—CAMBRIAN—SILURIAN.

As stated in Chapter III., the stratified formations are usually arranged under three great divisions—the Palæozoic, or Ancient-Life; the Mesozoic, or Middle-Life; and the Cainozoic, or Recent-Life; each division being characterised by certain organic remains that do not occur in the others. The Palæozoic comprises the Cambrian, Silurian, Devonian, Carboniferous, and Permian systems, all more or less fossiliferous, and affording evidence of the kind of life that then peopled the lands and waters, and to some extent also of the physical conditions under which these forms existed. Under *Lower Palæozoic* we comprehend the Cambrian and Silurian, and indeed all those still older slates and schists in which indications of fossils have been detected. But beneath the lowest known fossiliferous strata there occurs in almost every country closely associated with, and immediately overlying the granitic rocks, a large development of crystalline schists in which no fossil remains have yet been discovered. These schists are generally known, at least to British geologists, as the Metamorphic or Hypozoic (Under-Life) strata, and require, before entering upon the fossiliferous formations, a brief but systematic notice.

The Metamorphic Strata.

These strata, so typically displayed, for example, in the Scottish Highlands, consist of gneiss, quartzite, mica-schist, hornblende-schist, chlorite-schist, clay-slate, and

occasional beds of granular limestone. Being bent, contorted, and cleaved, their stratification is often so obscure that it is difficult to determine whether certain serpentines and steatites are in dykes and veins, or in true stratified arrangement. On the whole, they are highly crystalline strata—gneiss being composed of quartz, felspar, and mica; quartzite of granular quartz; mica-schist of quartz and mica; and so on of the others, which are usually named after their most prevalent ingredient. As schists, they consist of irregular and crumpled laminæ, (*foliated*, in technical language,) and contain independent crystals of garnet, tourmaline, felspar, iron-pyrites, and other accidental minerals. Some of the gneissic rocks have even a porphyritic texture, and were it not for certain lines and laminæ indicating stratification, it would be difficult to distinguish between them and some varieties of granite. In whatever condition they were originally deposited,—that is, whether as sands, clays, muds, or gravels,—they have undergone, in course of ages, such a degree of metamorphism, through pressure, heat, chemical action, and the like, that they are now all, less or more, crystalline; and if they ever contained fossils, all traces of these seem to be obliterated by this metamorphic process. We say, "seem to be obliterated," for it may yet happen in some localities where metamorphism has not been carried to a high degree, that organisms may be detected, and thus confirm the opinion that life commenced on this globe with the deposition of the first-formed strata. Entertaining this opinion, and knowing that it is impossible in the existing state of our knowledge to determine the commencement of life, we have ranked them under the present head as a convenient, and, on the whole, not unnatural arrangement.

Metamorphic strata are largely developed, we have said, in the Scottish Highlands; they occur also in Cumberland and Wales; in Ireland; and along the flanks, indeed, of all the older and granitic mountain-chains in the world. From their unequal hardness, they are usually weathered and wasted into fantastic peaks and pinnacles, which confer on these hill-ranges that wild and rugged scenery

so characteristic of their age and formation. Indeed, wherever they occur they produce that jagged and splintery aspect (the *aiguille*, or needle-top of the French) so characteristic of Alpine scenery; at the same time that they are worn into gorges and ravines of greater wildness and irregularity than are to be found in the rocks of any other system. From their strata are obtained roofing-slate, slate-slabs, limestones, marbles, and serpentines; and the veins that traverse them are the frequent repositories of metallic ores—tin, copper, iron, silver, gold, and platinum.

Cambrian System.

The *Cambrian System*, so termed by Professor Sedgwick because largely developed in Wales, (the ancient Cambria,) consists in the main of a great thickness of dark, semi-crystalline slates, gritstones, and occasional limestones. Fossils are seldom found in the lower portion, but as we ascend they become more frequent, and gradually merge into those of the Lower Silurian. Still older, perhaps, than the Cambrian, are certain slates and schists occurring in the Hebrides, in the neighbourhood of Lake Huron in America, and along the frontier of the St Lawrence. These "Hebridean," "Huronian," and "Laurentian" strata—for by these terms they are generally known—contain obscure traces of fucoid or sea-weed-like plants, worm-tracks and burrows, fragments of sea-pen-like zoophytes, and portions of trilobites. As yet these Hebridean and Laurentian rocks are the oldest in which traces of life have been detected, and as their organic forms are closely akin, or even identical with those of the lower Cambrian, it seems most convenient and natural to arrange the whole, from the undoubted Silurians downwards to the lowest fossiliferous beds under the Cambrian system. Taking this view, we get an intelligible basement, separable from the metamorphic and non-fossiliferous schists on the one hand, and distinct from the highly-fossiliferous Silurians on the other. And if it shall hereafter be found that these Hebridean and Lau-

rentian rocks are really of older date than the Cambrian of Sedgwick, and contain some life-forms peculiar to themselves, it will even then be better to rank them as lower Cambrian, than to cumber the science, in its present progressive state, with an additional and merely provisional Life-System.

And here, before entering on the fossiliferous systems, it may be useful to those who know little of Botany or Zoology to observe, that in dealing with fossil forms, Palæontology (Gr., *palaios*, ancient, *onta*, beings, *logos*, reasoning—the science of ancient life) adheres as closely as the subject will permit to the classifications of the botanist and zoologist. The species, genus, or even family may be extinct, but the orders in general remain; and the palæontologist by careful comparison arranges his objects as closely as their structure can indicate along with their living affinities. He speaks of the *Flora* and *Fauna* of a system, meaning thereby its vegetable and animal remains, just as the naturalist applies these terms to the living vegetables and animals of a country. Referring to the organisation of plants and animals, he speaks of lower and higher forms; to their geographical habitats, as aquatic, amphibious, terrestrial, fluviatile, lacustrine, marine, &c.; and to their relative structures, as flowerless and flowering, invertebrate and vertebrate. Thus, *Flowerless* plants, like the mushrooms, lichens, sea-weeds, ferns, equisetums, and clubmosses, are simpler or lower in structure than the *Flowering*, which embrace the grasses, sedges, palms, cycads, coniferous trees, shrubs, and true timber trees, like the beech, ash, and oak. So also *Invertebrate* animals, (those without back-bones,) as sponges, zoophytes, sea-urchins and star-fishes, worms, barnacles, crabs, and shell-fish, are lower than the *Vertebrate*, or back-boned, which include the fishes, reptiles, birds, and mammalia. Though technical terms are usually employed to designate the different orders, families, and genera, we shall avoid them as much as possible, using familiar terms instead; and yet no ordinarily informed mind need have difficulty in understanding that mollusca (Lat., soft animals) means shell-fish; crustacea,

(Lat., *crusta*, a hard covering or crust,) crabs and losbters; or annelida, (Lat., *annellus*, a little ring,) animals composed of a series of rings, like the leech and earth-worm. Where general technicalities are used, we shall explain them as they occur; but the scientific names of fossil genera and species, in an outline of this kind, are merely mentioned incidentally,—it being of more importance for the reader to know, for example, that gigantic crustacea occur in the Old Red Sandstone, than that these crustacea are known by the names of pterygotus and eurypterus. What we aim at—and our limits will permit of nothing more—is a simple sketch: details and reasonings can be found in other volumes by those who wish, or are prepared for, the systematic study of Geology.

Silurian System.

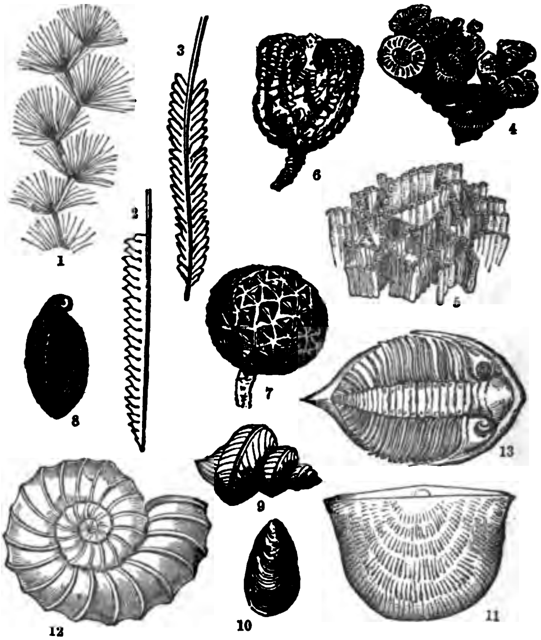
The *Silurian System* (so named by Sir Roderick Murchison from its typical development in the district between England and Wales inhabited by the ancient British tribe of the Silures) consists in the main of a great variety of argillaceous strata, (slaty and shaly,) limestones, sandstones, gritstones, and occasional pebbly conglomerates. Throughout the whole there are frequent beds of trap-ash and interstratified greenstones, indicating the presence of volcanic action in and around the seas during the deposition of the system; and to this action is usually attributed the hardening and altering of many of the lower and older strata. In the lower portion the hard sandstones and slaty beds contain comparatively few fossils, and are in mineral characters closely associated with the Cambrian; but in the upper portion the shales and limestones are replete with marine organisms; hence the usual division of the system into Lower and Upper Silurian. Throughout the whole, however, the strata, whether argillaceous, (clayey,) arenaceous, (sandy,) or calcareous, (limy,) bear obvious evidence of their sedimentary origin, and in this respect differ greatly from the schistose and semi-crystalline rocks that lie beneath them. The following synopsis of the strata, as they occur in the

typical district of Siluria, represents a thickness of eight or nine thousand feet, and is that upon which Sir Roderick mainly founded the system:—

UPPER.	Finely-laminated reddish sandstones and shales, locally known as "Tilestones." Micaceous gray sandstones of varying thickness, Argillaceous limestone, (Aymestry.) Calcareous shale, with concretions of limestone, (Ludlow.) Concretionary limestone and argillaceous shale, (Wenlock.) Shelly limestone and sandstone, (Woolhope and May-hill.) Gritty sandstones and shales (Upper Llandovery.)
LOWER.	Grits and sandy shales, (Lower Llandovery.) Thick-bedded white freestone, (Caradoc sandstone.) Dark-coloured flagstones and slates, (Bala beds.) Dark-coloured calcareous flags, bands of limestone, and gritty flagstones, (Longmynd, or "Bottom rocks.")

With the exception of some indistinct fragments of land-plants in the uppermost beds, the whole remains are eminently marine, and give evidence of conditions favourable at once to exuberance and variety of invertebrate life. Among the prevailing and characteristic fossils are *fucoids*, or sea-weed-like plants, (chondrites); occasional *spongiform* organisms, (acanthospongia); *corals* in great variety, and often so abundant as to constitute reef-like masses of limestone, (heliolites, cyathophyllum, catenipora); radiate animals, as *encrinites* and *star-fishes*, (cyathocrinus, actinocrinus, protaster); *annelids*, or sea-worms, as evidenced by their tracks and burrows in many of the sandstones, (serpulites, scolites); *graptolites*, or sea-pen-like organisms of many kinds, (graptolithus, diplograpsus); *shell-fish* of every order, but with a preponderance of brachiopods, (lingula, orthis, atrypa); crustaceans in numerous genera of *trilobites*, with three-lobed bodies, (asaphus, calymene,) and *eurypterites*, with broad swimming limbs and lobster-like forms, (eurypterus); and in the uppermost strata (by some regarded as passage-beds into the Devonian system) the fin-spines, teeth, and bones of small ganoid or enamel-scaled fishes.

Strata characterised by the preceding fossils are largely developed in many countries, and in particular along the flanks of the older mountain-chains, where they appear



1. Oldhamia; 2. Graptolithus; 3. Diplograpsus; 4. Cyathophyllum; 5. Catenipora; 6. Taxocrinus; 7. Cystidea; 8. Atrypa; 9. Murchisonia; 10. Lingula; 11. Strophomena; 12. Lituite; 13. Petracops, (trilobite.)

in rounded and less abrupt forms than the rugged and splintery peaks of the harder and more crystalline metamorphic strata. They occur in Wales, in Cumberland, and Westmoreland; along the entire south of Scotland; south-east of Ireland; in south of France, Spain, Scandinavia, Russia, and Bohemia; in Asia Minor; along the Himalaya and Altai ranges; in Australia and New Zealand; along the Andes, Rocky Mountains, and Appala-

chians in America. Though usually appearing as well-marked, alternating marine strata, they are often hardened and metamorphosed into siliceous grits and semi-glistening slates, and where this occurs they are traversed by frequent lodes and veins rich in metallic ores. Platinum, gold, silver, tin, mercury, and manganese, are among the most abundant products; and it is especially worthy of notice that the richest auriferous veins in the Ourals, California, Australia, and New Zealand, are situated in schists of the lower Silurian and Cambrian age.

Such is a brief outline of the metamorphic and lower Palæozoic strata—their lithological or mineral characters, their palæontological or fossil characters, and their geographical distribution. Metamorphic rocks—that is, rocks which have undergone an internal change through heat, pressure, chemical action, or, otherwise—may and do occur in connexion with every formation; but the "Metamorphic System" usually so called is that which underlies in every region the lowest fossiliferous strata, and consists in the main of gneissic rocks, quartzites, granular limestones, mica-schists, chlorite-schists, and clay-slates—all more or less shewing slaty cleavage, crumpled or foliated in their lamination, containing accidental minerals, as garnet, tourmaline, and chiastolite, and frequently intersected by quartz and metalliferous veins. Above these, but partaking in some degree of their schistose and sub-crystalline character, occur the strata of the "Cambrian System," which imbed, as far as yet discovered, the first traces of life on our globe, and these consist of obscure fragments of sea-weeds, worm-tracks and burrows, and small crustaceans. Still less metamorphosed, and assuming the character of ordinary sandstones, grits, shales, and limestones in vast succession, appear in ascending order the strata of the "Silurian System." In the lower

portion the beds are very similar to those of the Cambrian, both in their composition and fossils; but in the upper portion the fossils greatly increase in numbers, and belong to higher orders of being. Throughout the whole series the fossils are eminently marine, and indicate the existence of wide-spread seas, where sea-weeds, sponges, corals, star-fish, shell-fish and crustacea, swarmed in vast profusion. Unless in some indistinct club-moss-like fragments, we have no evidence of the terrestrial life of the period; and certain culmy or anthracitous shales are usually ascribed to the accumulation of marine rather than of terrestrial vegetation. Notwithstanding this predominance of marine conditions, the reader must guard against the absurd idea, occasionally entertained, that the Cambrian and Silurian were periods of all but universal ocean. Formations of great thickness and extent necessarily imply wide-spread lands from which the sediments were derived, and the vastness of these palæozoic systems confutes at once the absurdity of an ocean all but universal. In all such estimates, too, it must ever be borne in mind that the existing land forms little more than a fourth of the earth's surface—the rest being covered with water, which prevents even an approximation to the relative extent of sea and land in bygone ages. The prevailing and distinctive fossils of the systems are its corals and cystideæ, its graptolites and deep-water brachiopoda, its trilobites and eurypterites—the corals being so abundant as to form reefs of limestone, the graptolites layers of culmy shale, and the trilobites to contribute largely to those bituminous and oil-bearing strata which of recent years have been discovered in connexion with the palæozoics of the United States and Canada. Industrially, the system yields limestones and marbles, building and paving-stones, roofing-slates, but rather soft and perishable; and from its veins are obtained gold, platinum, silver, and other metals, either native or in ores.

VI.

MIDDLE AND UPPER PALÆOZOIC: DEVONIAN—CARBONIFEROUS—PERMIAN.

WHILE the Cambrian and Silurian Systems are generally regarded as *Lower* Palæozoic, the Devonian is ranked as *Middle*, and the Carboniferous and Permian as the *Upper* members of the period. Though treated as separate systems, there is often a great similarity, and necessarily so, between the upper strata of one system and the lower strata of that which immediately succeeds it. These intermediate strata are spoken of as "passage-beds," and mark, both by their composition and fossil contents, the transition from one epoch to another. Thus, in passing from the Silurian to the Old Red Sandstone or Devonian, we find, particularly in Britain, a considerable thickness of flagstones and tilestones, which have been ranked sometimes with the one system and sometimes with the other; but which, from their greater abundance of fish-remains, are, perhaps, more correctly arranged as the basement or beginning of the Old Red Sandstone. Not that we regard the Silurian, as some have done, "a great period of invertebrate life;" but simply because the fishes found in these passage-beds are identical with those abounding in the Old Red Sandstone, and can be more intelligibly considered along with them than with the few and doubtful fragments which occur in the upper beds of Siluria.

OLD RED SANDSTONE OR DEVONIAN.

In the British Islands the coal-measures usually rest upon a series of red sandstones and pebbly conglomerates,

and are in turn overlaid by another series of red sandstones and magnesian limestones. By miners and the earlier geologists the former was named the "Old Red," and the latter the "New Red." The term *Old Red Sandstone* has reference, therefore, to the prevailing colour of the strata; but as the system contains gray sandstones, yellow sandstones, and white sandstones, as well as red sandstones, the name is not altogether appropriate. The title *Devonian*, on the other hand, refers to the strata as exemplified in Devonshire; but as a portion of the system is not represented in that county, this designation is also partial and deficient. In the meantime we may use either term as a provisional designation—understanding thereby that suite of sandstones, grits, conglomerates, schists, shales, marls, and limestones that are interposed between the Silurian and Carboniferous Systems. In Scotland the lower portion consists of thick-bedded conglomerates, red and gray sandstones and flagstones, and bluish slaty shales; the middle of pebbly and gritty sandstones, calcareous shales, and concretionary limestones; and the upper of red and yellow fine-grained sandstones, with mottled shales and marls between. In Hereford the system consists essentially of red and yellowish sandstones, calcareous shales, and cornstones or concretionary limestones; while in Devonshire it consists, in ascending order, of gray and red grits, gray, red, and greenish schists, gray fossiliferous limestones, slaty shales, and calcareous flagstones. Terrestrial life is scantily indicated, by fronds of ferns and unknown stems, in Scotland and Ireland; but in Canada thin seams of coal give evidence of a more abundant flora.

Tabulating the preceding details, and arranging the whole system as it occurs in the British Islands into lower, middle, and upper groups, we are presented with the following synopsis:—

UPPER.	Yellow and white sandstones, generally fine-grained, alternating with layers of red and chocolate-coloured shales; red quartzose sandstones, usually underlaid by, or alternating with, beds of pebbly conglomerate.

MIDDLE.	Brick-red quartzose and pebbly sandstones alternating with mottled shales; layers of pebbly conglomerate; concretionary limestones or cornstones, associated with thick-bedded marly shales. In Devonshire, schists, with sandstones and thick masses of marine limestone.
LOWER.	Reddish-gray sandstones with enclosed pebbles; gray micaceous flagstones and limestones, with intervening beds of bluish shale; hard dark flagstones; and thick masses of large pebbled conglomerate. In Devonshire, sandstones, with slaty schists and some impure limestones.

In Scotland the prevailing and characteristic fossils are *sea-weeds* (fucoids) and obscure *land-plants* (ferns and club-mosses;) several genera of *crustaceans*, often of large dimensions, (pterygotus, eurypterus, stylonurus, &c.;) and a vast variety of *fishes*—bone-encased, as coccosteus, pterichthys, and cephalaspis; with large enamelled scales, as holoptychius, glyptolepis, and osteolepis; and with minute enamelled or shagreen-like scales, and armed with fin-spines, as acanthodes, diplacanthus, and climatius. In the Old Red of Scotland no corals, trilobites, or shells occur; but in Devonshire the calcareous strata are replete with them, and bear evidence of a marine life as exuberant as that of the Upper Silurian. In the north of Europe and in North America corals, trilobites, shells, and fishes occur in the same strata, and thus complete the life of the system which, by local geographical causes, had been separated in the area of Britain. In these Devonian strata the characteristic fossils are *corals*, (heliopora, cyathophyllum, favosites); *trilobites*, (bronteus, calymene); and *shell-fish*, as terebratula, spirifera, cucullæa, calceola, megalodon, Murchisonia, and clymenia.

As a system, the Old Red Sandstone, in one or other of its groups, is widely distributed over the globe. It is largely developed in the north and east of Scotland; in the south and west of England; the south of Ireland; in Belgium and Germany; very extensively in the flats of Russia and Central Europe; in Siberia and Tartary; along the lower Himalayan ranges; in Brazil; and in great force also in the United States and British North

America. Wherever it occurs, conglomerates and grits, sandstones and flagstones, shales and schists, all more or

1. Megalodon; 2. Spirifera; 3. Stringocephalus; 4. Cucullæa; 5. Clymenia; 6. Adiantites; 7. Eurypterus; 8. Cheiracanthus; 9. Cephalaspis.

less partaking of a reddish hue, prevail, with occasional beds of cornstone and gray fossiliferous limestones. So far as is yet known with certainty, the vegetable life of the epoch consists of aquatic plants, ferns, and club-mosses; and the animal life of corals, encrinites, shell-fish, crustacea, and fishes. The existence of reptilian life is doubtful; and it is also undetermined whether certain portions of the system are of marine or of fresh-water

origin. In some areas, as in the British Islands, the strata are much broken up and intersected by trap eruptions; but, on the whole, there are fewer interstratifications and evidences of contemporaneous volcanic action than in the Silurian system. The industrial products derived from the Old Red Sandstone are building-stones of various quality; paving-stones or flagstones like those of Forfar and Caithness; and a variety of limestones and marbles. The metallic veins that traverse the system are of much less importance than those of the Silurian; but the amygdaloidal and felspathic traps are in many localities rich in rock-crystals, agates, carnelians, chalcedonies, jaspers, and similar ornamental minerals.

CARBONIFEROUS SYSTEM.

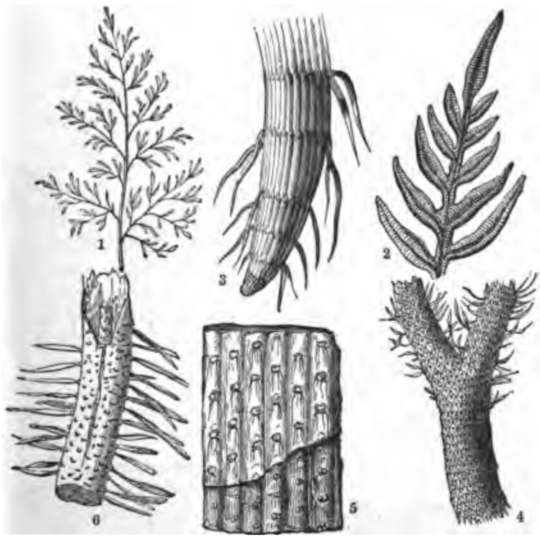
Immediately above the Old Red Sandstone, and in some localities inseparably associated with it by a series of passage-beds, occurs the Carboniferous or Coal-bearing system. Strata of more recent date—the Oolite, Chalk, and Tertiaries—yield coal of some importance, but in no degree comparable with that obtained from the palæozoic coal-fields of Europe and North America; hence the general adoption of the term "Carboniferous," (Lat. *carbo*, coal; *fero*, I bear.) As a system, it consists of several series or formations; but in all they consist of sandstones, limestones, shales, coals, and ironstones. These strata appear in every degree of admixture, as argillaceous limestones, calcareous shales, arenaceous shales, argillaceous ironstones, calcareous ironstones, &c.; but by the employment of such descriptive terms, an intelligible idea of their composition can be readily conveyed. In Britain, the system may, without much error, be said to be composed of three main series—the *Lower Coal-Measures*, the *Carboniferous* or *Mountain Limestone*, and the *Upper* or *True Coal-Measures*. Where developed, the lower group consists of sandstones, shales, thin coals, ironstones, and limestones, that indicate a fresh-water or estuarine origin; in the middle group, the limestones and shales are replete with marine fossils; and in the upper group, where the shales, thick coals, and

ironstones most abound, we have evidence both of terrestrial and estuarine conditions. Taking the system as usually subdivided by English geologists, we have the four following groups, which, with the exception of the Millstone Grit, are more or less represented in every British coal-field :—

1. Upper Coal-Measure.—A thick series of sandstones, shales, fire-clays, some impure limestones, ironstones, and coals. From its numerous seams of workable coal, this group is often spoken of as the "True Coal-Measures."
2. Millstone Grit.—Generally a local development of moderate thickness, consisting, for the most part, of compact gritty sandstones, with interstratified shales and thin seams of coal.
3. Mountain or Carboniferous Limestone.—A series of thick-bedded marine limestones, with occasional shales, sandstones, and thin seams of coal.
4. Lower Coal-Measures.—A great thickness of fine-grained sandstones and grits, with shales, fire-clays, ironstones, shell and fresh-water limestones, and thinnish seams of coal.

As may be expected in a system partly estuarine, partly marine or pelagic, (Gr. *pelagos*, the deep sea,) and partly terrestrial, the fossils are extremely varied, each great habitat contributing its quota to the flora and fauna of the period. We can only notice a few of the more characteristic and prevalent. The *Flora*, or plant-life, of the system is one of its most distinctive features—the exuberance of vegetation giving rise to those numerous seams of coal which occur throughout, but more particularly in the upper formation. Coal is but compressed and mineralised vegetable matter, and its various kinds (anthracite, cannel, splint, caking, &c.) depend partly on the state in which the plants were accumulated, but mainly on the chemical changes which the mass has undergone since formation. Thus, where coal results from vegetation that has grown *in situ*, like peat-mosses and cypress-swamps, it will be pure and homogeneous in texture; where it has arisen from drifted debris, it will be more laminated and earthy; and vegetable masses long macerated in shallow waters will give rise to a coal very different from that produced by fresh and suddenly-covered-up growths.

The coal-forming plants, as far as can be ascertained from their altered and fragmentary nature, have grown partly on dry land, but largely in swamps, and in all likelihood in estuarine and marine flats within the influence of inundating and tidal waters. They consist of coniferous or pine-like trees, (araucarites, favularia, knorria); of tree-ferns, (sphenopteris, pecopteris, neuropteris); of club-mosses and equisetums of gigantic growth, (lepidodendron, calamites, hippurites); and of a large assemblage of trunks,

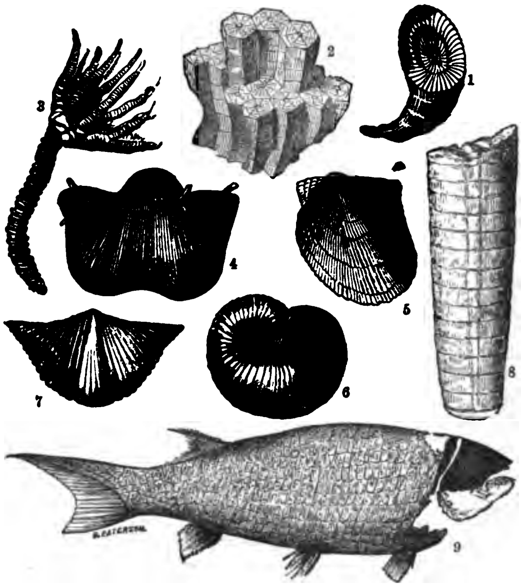


1. Sphenopteris; 2. Pecopteris; 3. Calamites; 4. Lepidodendron; 5. Sigillaria; 6. Stigmaria.

stems, leaves, and roots, to which the botanist is at a loss to find any existing analogues, (sigillaria, stigmaria, bothrodendron, ulodendron, and others.) Whatever their affinities to existing plants, they seem to have enjoyed most favourable conditions of growth, and to have flourished for ages over wide areas in a state of luxuriance unequalled by the rankest exuberance of existing tropical

forest-growths. Their luxuriance is evidenced by the thick and wide-spread seams of coal they now form; and the numerous seams in the same coal-field shew that they must have flourished for ages, forest-growth after forest-growth, on the surface of an alternately submerged and elevated, but in the main gradually subsiding land.

The *Fauna* or animal-life of the period is also partly marine, partly estuarine or lacustrine, and partly terrestrial. From the general absence of marine shell-fish, corals, and other zoophytes in the lower coal-measures, they are usually regarded as of fresh-water or estuarine



1. Clisiophyllum; 2. Lithostrotion; 3. Woodocrinus; 4. Productus; 5. Aviculopecten; 6. Bellerophon; 7. Spirifera; 8. Orthoceratite; 9. Eurylepis.

formation; but it must be confessed that many of the crustacea and fishes are common to the entire system.

The mountain limestone abounds in corals and encrinites, and many of its thickest strata are but reefs of the one, or masses of the broken stems and arms of the other. Grouping all the series into one life-system, we have *corals*, (cyathophyllum, clisiophyllum, syringopora); *encrinites*, (cyathocrinus, apiocrinus, Woodocrinus); *star-fishes* and *sea-urchins*, (asterias, archæocideris, palæchinus); *annelids*, and their tracks and burrows, (serpulites, spirorbis, arenicolites); *crustaceans*, minute and bivalved, (cypris); trilobites, (Phillipsia); and larger king-crab-like forms, (bellinurus, eurypterus); beetle-like *insects*, (curculionides); *molluscoida*, or compound forms, like the flustra or sea-mat, (retepora, fenestella); true *molluscs*, or shell-fish of every order, (productus, terebratula, spirifera; aviculopecten, anthracosia, modiola; euomphalus, bellerophon, loxonema; nautilus, goniatites, orthoceras); *fishes*, and fish-remains in teeth, scales, and fin-spines, (palæoniscus, megalichthys, rhizodus, gyracanthus); *coprolites*, or fish-droppings; and *reptiles*, aquatic and terrestrial, in bones, teeth, and footprints, (archegosaurus, anthracosaurus, dendrerpeton.) In fact, all the great classes of life, with the exception of birds and mammals, appear in the Carboniferous system; thus shewing a vast advance as compared with the fauna of the Silurian and Cambrian periods.

The Carboniferous system, in one or other of its members, is widely distributed over the globe. It is not asserted by this that the strata in distant regions are precisely contemporaneous, but merely that they contain the same aspect or *facies* of fossil life, and that they have been deposited under closely analogous conditions. They occur largely and valuably in our own islands; in Spain, France, Belgium, Germany, and Eastern Europe; in Hindostan and China; in Australia; in Chili and Brazil; in Canada and the Arctic islands; and most extensively in the United States of America. It must be observed, however, that in many countries the coal-fields belong not to the true Carboniferous system of the Palæozoic epoch, but to the Oolitic, Cretaceous, and Tertiary systems; and to these later periods are to be ascribed most of the coals of India and the Indian Archipelago, the Philippine and

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immediately underlying the coal formation, were termed by the earlier geologists the *Old Red Sandstone*, so the red sandstones, magnesian limestones, and marls that occur above it were designated the *New Red Sandstone*. When fossils, more than mineral characters, became the tests of formations and systems, it was found that the lower portion of this new red sandstone contained plants, shells, fishes, and other organisms identical with those of the Carboniferous system, or, in other words, had a palæozoic aspect, while those contained in the upper portion had decided mesozoic affinities. This led to a separation of the New Red Sandstone into two distinct systems, or sub-systems—the lower termed the *Permian*, after the province of Perm, in Russia, where the strata are very fully developed; and the upper the *Trias*, or *Triassic*, from its consisting of three well-marked series of strata in Germany, where the whole is very typically displayed. Instead of the terms Permian and Trias, some foreign geologists employ, for uniformity's sake, the terms *Dyas* and *Trias;* but we follow the usage of British geologists, and abide by those designations the reader is most likely to meet in with during the further prosecution of his studies.

The Permian system, as developed in England, consists in its lower portion of alternations of reddish sandstones, grits, and shales; and in its upper of whitish and cream-coloured magnesian limestones, calcareous flags, and marls. In Germany, the arrangement of the strata is very similar, with the addition of some slaty shales impregnated with copper-ore, (*kupfer-schiefer*); but in Russia, where some of the marls are also cupriferous, the sandstones and grits prevail, and there is altogether a greater prevalence of plant-remains, and in the lower strata even seams of impure coal. Whatever the composition of the strata, and wherever they occur, they appear to have been deposited in seas of moderate depth, and present abundant evidence of their origin in corals, encrinites, shell-fish, and other marine organisms. In some districts they rest unconformably on the upturned coal-measures, while in others they graduate so insensibly from them, that were it not

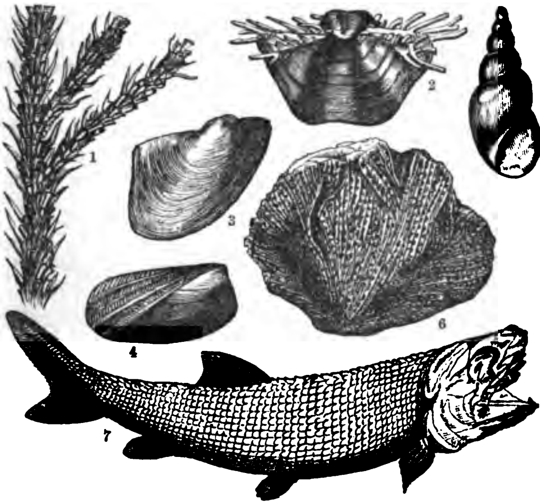
for the paucity of plant-remains and the generally redder colour of the strata, it would be impossible to say where the one ends and the other begins.

The following tabulation exhibits the succession of Permian strata as they occur in the areas of Durham and Yorkshire—by far the most typical and best investigated of our New Red Sandstone districts:—

MAGNESIAN LIMESTONE.	Laminated limestone, with layers of coloured marls. Gypseous marls—red, bluish, and mottled. Magnesian limestone, often in thick beds, and of various texture and structure, and usually cream-yellow or white. Marl slates—impure, soft, calcareous flags.
RED SANDSTONE.	Red quartzose sandstones, with red and purple marls. The grits are occasionally pebbly, and pass into beds of pebbly conglomerate.

The Permian fossils, we have said, have more or less a carboniferous aspect, and in many instances both genera and species are identical. The plant-remains consist of sea-weeds, (chondrites); ferns, and club-mosses, (neuropteris, pecopteris, caulerpa, psaronites, lycopodites); coniferous-looking stems, (lepidodendron, walchia); fossil-fruits, (cardiocarpum); and leaves like those of the fan-palm and cycas. The red sandstones and shales are generally barren of fossils, but the limestones and calcareous flagstones contain spongiform organisms, (bothroconis); foraminifera, (textularia); corals of elegant forms, (calamopora, calophyllum); encrinites and sea-urchins, (cyathocrinite, aschæocidaris); annelids, (serpula, spirorbis); minute bivalved crustaceans, (cythere,) but no trilobites or eurypterites; and mollusca in every known order, though not in equal abundance with the strata of the mountain limestone, (fenestrella, producta, strophalosia, mytilus, schizodus, natica, pleurotomaria, &c.) Several of the smaller ganoid fishes, (palæoniscus, platysomus,) are common to the Carboniferous and Permian systems; but up to this point of time, all, or nearly all, of these fishes have been heterocrecal,—that is, having unequally lobed tails,—a peculiarity that runs through the whole of the Palæozoic systems. Besides fishes, we have also reptiles,

aquatic and terrestrial, and of higher organisation than any yet discovered in the coal-measures; and if American



1. Caulerpa; 2. Productus horridus; 3. Bakevellia; 4. Pleurophorus; 5. Macrocheilus; 6. Fenestrella; 7. Palæoniscus.

geologists be not mistaken as to the age of their formations, bird footprints and mammalian bones also make their appearance for the first time in the Permian system.

Strata of Permian age are found in England, Scotland, and Ireland; in France, Germany, and Russia; in Southern Africa; and in North America. Where seams of coal appear in the lower portion of the system, it is often impossible to draw a line of distinction between Permian and Carboniferous, just as it is difficult, in the absence of fossils, to distinguish between Permian and Triassic. Though erected into a separate system, there is much both in its mineral composition and fossil contents that connects it with the underlying Carboniferous; hence some geologists regard it more as the capping or close of the

coal period, than a separate and independent life-system. It is convenient, however, to retain the distinction in the meantime, the student ever remembering that the so-called *systems* are by no means of equal value, and that where no great physical break occurs between two conterminous formations, there must of necessity be a number of species common to both.

Such are the Middle and Upper Palæozoic systems—the Old Red Sandstone or Devonian, the Carboniferous and the Permian. In the Lower Palæozoic, the life-forms were chiefly or wholly *invertebrate;* in the upper, the *vertebrate* forms of fishes and reptiles are superadded, and these in considerable force, both in point of numbers and species. Though differing widely in the conditions under which they were formed, there is a certain general resemblance among the upper palæozoic systems, which permits their treatment under one chapter—the "passage-beds" between the Old Red and Coal, and between the Coal and Permian, linking them together, as it were, into one great category of vitality. As a separate system, the Old Red Sandstone is chiefly characterised by a preponderance of pebbly and arenaceous beds, which indicate comparatively shallow waters of deposit, by a paucity of vegetable remains, and for the first time in the stratified systems, by a great exuberance of fish-life; the Carboniferous by a vast variety and admixture of sediments, by evidences of terrestrial and estuarine, as well as marine life, and especially by the enormous profusion of its vegetation; and the Permian by a recurrence of red-coloured sediments, and by an accompanying paucity of plant-remains. Fishes that make their appearance so doubtfully in the upper beds of the Silurian, come out in great force in the Old Red Sandstone; so strongly, indeed, as to warrant the suspicion that they existed in greater abundance during

the Silurian epoch, though yet undiscovered by Geology. Reptiles and fishes having reptilian affinities occur during the Coal period, but they appear in more decided character—aquatic and terrestrial—towards the close of the Permian.

Though birds and mammals are unknown in Palæozoic ages, all the lower forms of life are obviously on the advance—families and genera dying out, and others more highly organised making their appearance. Sigillariæ, stigmariæ, lepidodendra, bothrodendra, and other forms of carboniferous plants, disappear from the land; graptolites, trilobites, and eurypterites die out from the waters. As mere sediments, the strata of the Silurian may differ little in composition from those of the Carboniferous, and the red sandstones of the Old Red may be undistinguishable from those of the Permian; but they differ widely in their areas and in their organic remains, shewing clearly that there had been different dispositions of sea and land, and difference in those external conditions which are the great regulators of the exuberance and distribution of life, both on the land and in the waters. As chapters of world-history, the upper palæozoic formations are of curious and varied interest; as industrial repositories of building-stones, limestones, marbles, fire-clays, alum-shales, coals, ironstones, and ores of lead, zinc, and other metals, they are unequalled among the stratified systems.

VII.

LOWER AND MIDDLE MESOZOIC: TRIASSIC—OOLITIC.

As tabulated in Chapter III., the Mesozoic Cycle embraces the Triassic, Oolitic, and Cretaceous systems. The term implies that the life of these systems holds a *middle* or intermediate place, both in position and characteristics, between the Palæozoic on the one hand, and the Cainozoic on the other. For a similar reason, they were termed *Secondary* systems by the earlier geologists, and this term is still in use alike in popular and in scientific descriptions. For palæontological reasons, it is customary to rank the Trias as lower, the Oolite as middle, and the Chalk as upper secondary, though it must be confessed that this arrangement is more of local than general importance. We follow it here, as preparing the reader for the better comprehension of distinctions he is sure to meet with in the further prosecution of his studies.

The Triassic System.

The *Triassic system*, or *Trias*, is so named because where it is fully developed (as in Germany) it consists of *three* well-marked series of strata—the *Bunter sandstein*, or variegated sandstone; the *Muschelkalk*, or shell-limestone; and the *Keuper marls*, or marls, more or less impregnated and coloured by the ores of copper. The Bunter, or lower portion, is composed, as the name implies, of *variegated* (red and white) sandstones, and pebbly conglomerates; the Muschelkalk of gray *shelly* limestones, with beds of magnesian limestone and gypsum; and the Keuper, or upper portion, of saliferous and gypseous shales,

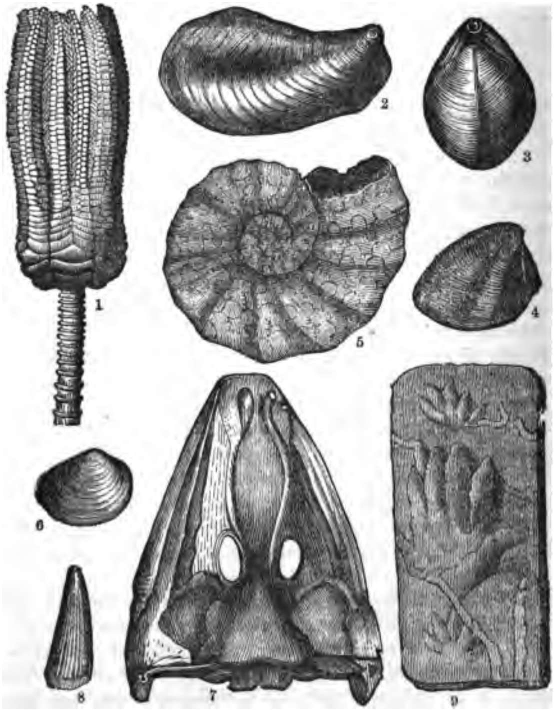
with beds of mottled sandstones and impregnations of *copper*. In England, where it is generally known as the *Upper New Red Sandstone*, it consists of two series only—red and white sandstones, with quartzose conglomerates at the base, and variegated marls and clays holding irregular beds of rock-salt and gypsum in the upper portion. Or tabulating the details as given in the Memoirs of the Geological Survey, we are presented with the following succession :—

KEUPER.	1. Mottled (gray, green, and red) clays and marls. 2. Red marls, with sandy laminæ and sandstones. 3. Red and blue clays, with rock-salt and gypsum. 4. Water-stones, (laminated sandstones.)
BUNTER.	5. Soft red variegated sandstone. 6. Coarse red sandstone and conglomerate. 7. Soft red and variegated sandstone.

On the whole, it may be described as a system of reddish sandstones and shales, with local developments of pebbly conglomerates, beds of shelly limestone, and masses of rock-salt and gypsum. From the prevalence of rock-salt in the new red sandstone of Britain, (Cheshire, the Tees, Belfast, &c.,) it was at one time termed the *Saliferous* system; but as rock-salt is a product of other systems in many parts of the world, the name is by no means distinctive, and is now but rarely employed. Whatever the composition of its strata, they are all eminently marine, and give evidence of seas of moderate depths, whose gravel beaches, sandy shores, mud lagoons, shell-beds, and saline waters were successively converted into conglomerates, sandstones, marls, limestones, rock-salts, and gypsums.

Like other sediments deeply coloured by the peroxide of iron, the red sandstones of the Trias are rarely fossiliferous, and it is chiefly in the more carbonaceous shales and calcareous strata that organisms are preserved. The FLORA is especially scanty in European areas, and consists of plants allied to the equisetum and hippuris, (equisetites, calamites); of ferns, (neuropteris, pecopteris); of leaves and stems akin to the cycas and zamia, (cycadites, pterozamites); of palm-like leaves, (palmacites); and of

true coniferous trees, (araucarites and walchia.) In Europe we have carbonaceous shales, but no true triassic coals; and it is only in North America and Eastern Asia that strata, supposed to belong to this epoch, are found to contain coal-seams of available thickness. The FAUNA, though mainly marine, shews comparatively few corals; but star-



1. Encrinite; 2. Avicula; 3. Terebratula; 4. Myophoria; 5. Ceratites; 6. Estheria; 7. Skull of Labyrinthodon; 8. Tooth of do.; 9. Footprints of do.

fish, (aspidura,) and encrinites, (encrinus liliiformis,) are common in the muschelkalk; as well as minute crusta-

ceans, (estheria,) lobster-like forms, (pemphix,) and beetle-like insects. Of shell-fish, in the same calcareous beds, we have brachiopods, (terebratula, spirifer); true bivalves, (avicula, mya, plagiostoma); and cephalopods with coiled shells, (ceratites.) Fishes occur in considerable abundance, (saurichthys, gyrolepis, acrodus); and reptiles, aquatic and terrestrial, (labyrinthodon, phytosaurus, dicynodon,) are known from their bones and teeth, but more extensively from their footprints, (*ichnites*,) which mark in great profusion, and of all sizes, the upper surfaces of many of the flaggy sandstones, as in Dumfriesshire, Cheshire, Morayshire, Hildburghausen in Germany, and Connecticut in North America. Higher than reptilian life, bird footprints (ornithichnites) and bones, and the jaws and teeth of small marsupial mammals, (microlestes, dromatherium,) are by no means unfrequent; thus shewing that as we ascend in time, so in like manner we ascend in vital rank to higher and higher orders.

Strata of Triassic or Upper New Red Sandstone age, occupy a wide belt of England, stretching from Durham on the east to Lancashire on the west, and southward through Cheshire and Worcester to Somerset and Devon; in the basin of the Solway and south-west of Scotland; along the coast of Morayshire; the north of Ireland; in France, Germany, and the region of the Alps; in Southern Africa; Southern India; and largely in the United States of America. Wherever it occurs there is a great similarity among its cycadaceous plants; among the marine organisms of its calcareous strata; and, above all, in the footprints (bird and reptile) which mark the surfaces of its laminated sandstones. With the exception of building-stones, limestones, and gypsums, and some scantily-dispersed ores of copper and manganese, the main industrial product of the system is rock-salt, which occurs in beds and indefinite masses, often of great thickness and extent, and in every degree of purity, from transparent crystals to earthy admixtures scarcely worth the extracting. As affecting the landscape, Triassic districts are on the whole little varied, and rather flat and uniform in surface; partly from the absence of trap-rocks to break up and diversify, and partly

from the soft nature of their sandstones and marls, which have been greatly worn down and reduced to plains and valleys by aqueous and atmospheric action.

Oolitic System.

The *Oolitic system*, as developed in the British Isles, consists of three main members or formations—the Lias, the Oolite proper, and the Wealden. Though usually arranged under one system, there is in reality great differences between these respective formations, not only in their lithological aspects, and consequently in the conditions under which they were deposited, but also in the nature of their organic remains. The *Lias* (a local corruption of the word *layers*) consists chiefly of dark-coloured limestones and shales replete with marine organisms; the *Oolite* (Gr. *oon*, an egg, and *lithos*, a stone) of roestones or oolitic limestones, calcareous freestones, sands and clays, charged in like manner with marine fossils; while the *Wealden* (so called from the *wealds* or *wolds* of Sussex, where it was first examined) consists of shelly limestones, flaggy sandstones, and argillaceous shales, which from their imbedded organisms bespeak a fresh-water or estuarine origin. As no two seas are likely to present the same composition or alternation of strata, great differences may be expected between the Oolitic system of Britain and that of other countries; but wherever it occurs, argillaceous limestones, oolitic and coralline limestones, calcareous sandstones, and thick argillaceous sea-muds or shales may be said to be its leading characteristics.

In England, where the system occupies a considerable breadth of country, and lies undisturbed by igneous eruptions, the various members have been long the subjects of examination, and are usually arranged, under local names, in the following order:—

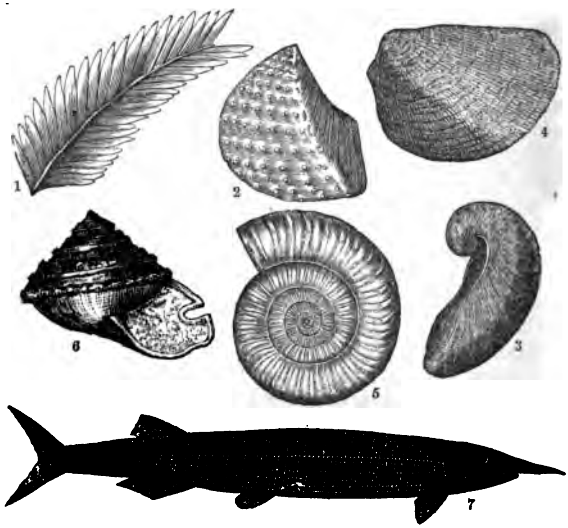
WEALDEN.	Weald clays—gray laminated clays and sandy flagstones. Hastings sands—sands, ferruginous sandstones, and sandy shales. Purbeck beds—shelly limestones and calcareous shales.

OOLITIC or JURASSIC.	Portland stone—fine-grained oolitic limestones, and sands. Kimmeridge clays and bituminous shales — "Kim coal." Coral rag—coarse-grained, shelly, and coralline oolite. Oxford clay—blue clays and shales, with limestone bands. Cornbrash — coarse shelly limestone, and Forest marble. Bath or great oolite—thick-bedded sandy oolites. Stonesfield slate—flaggy grits and oolite limestones. Inferior oolite, fuller's earth, and shales.
LIASSIC.	Lias clays and marlstones. Lias limestones and shales, with bands of jet.

As deposits consisting largely of calcareous shales and limestones, the oolitic strata are remarkably well-fitted for the preservation of organic remains; hence not only the abundance, but the perfection of their fossil contents. Among the vegetable forms we have impressions of *sea-weeds*, (halymenites); *equisetums* and other marsh-plants, (equisetites); *club-mosses*, (lycopodites); arborescent ferns of great beauty and luxuriance, (cyclopteris, pecopteris, otopteris); numerous *endogenous stems* and *leaves*, resembling the lily and aloe, (endogenites); abundant leaves and stems of *cycads* and *zamias*, (pterophyllum, pelæozamia, Mantellia); *palm-leaves* and *stems*, apparently allied to the screw-pines, (palmacites); and *coniferous leaves* and *fragments*, which, from their close resemblance to araucarias, yews, and cypresses, have been termed araucarites, taxites, cupressinites, and the like, to mark their characters and affinities. So abundant has vegetation been in many oolitic areas, that we are presented not only with bituminous shales, but with layers of jet and seams of coal, which in point of thickness and purity almost rival those of the carboniferous era. To this system belong most of the coals of Southern India, the Indian Archipelago, the Philippine Islands, Japan, Australia, Richmond in Virginia, and other localities which have been frequently mistaken for those of palæozoic origin.

The Fauna or animal-life of the Oolitic period is abundant and varied—marine forms largely preponderating in the Lias and Oolite, and estuarine in the Wealden. No sys-

tem in the British Islands has been more fully or carefully examined—exposure in sea-cliffs, in quarries and railway-cuttings in England, being unusually favourable for investigation. Taking its fossils in order of organisation, we have, first, various spongiform organisms, (spongia, talpina); foraminiferous shields, (polymorphina, flabellaria); and a great profusion of corals, in reef-like masses and detached, throughout the lias and oolite, (isastræa, montlivaltia, thamnastræa). Crinoidal remains occur in great beauty, (pentacrinite, apiocrinite); star-fish, (ophioderma, amphiura); and sea-urchins in greater variety than



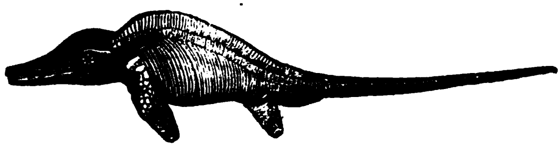
1. Pterophyllum; 2. Trigonia; 3. Gryphea; 4. Plagiostoma; 5. Ammonite; 6. Pleurotomaria; 7. Aspidorynchus.

in any preceding formation, (cidaris, nucleolites, hemicidaris.) Among the articulata we have marine annelids, (serpula, vermicularia); minute bivalved crustaceans, (cyprides); larger lobster-like forms, (glyphæa, eryon); and

insects of many orders, (libellulium, blattidium, bupres-tium.) The mollusca appear in vast profusion throughout the system—marine, of course, in the lias and oolite, and fresh-water or estuarine in the beds of the wealden. Among these, the bryozoa, or sea-mats, are represented by several genera, (diastopora, ceriopora); the brachiopods by many genera and species, (rhynconella, terebratula, spirifera); the true bivalves by still greater numbers, (gryphæa, gervillia, pecten, trigonia, pholadomya); the univalves, (nerinæa, pleurotomaria, trochus); and the cephalapods by a wonderful exuberance of externally-shelled forms resembling the nautilus, (ammonites,) as well as by others devoid of external shell, but furnished, like the cuttle-fish, with an internal one, (belemnites, belemnoteuthis,) and of whose existence this internal organism is in general the only evidence.

The vertebrate life of the period, though less profuse than that of the invertebrate, is yet largely preserved, and exhibits a great advance in organisation as compared with that of any of the preceding epochs. Ganoid and placoid fishes, in their teeth, fin-spines, or scales, occur in all the formations—the former in such genera as lepidotus, lopto-lepis, and dapedius; the latter in acrodus, hybodus, and asteracanthus. The forms and outlines of the ganoids or enamelled scales are often well preserved; but of the larger cartilaginous and shark-like placoids we have merely detached teeth and fin-spines, which shew considerable size and affinities to the cestracions of Australian seas. By far the most notable feature in Oolitic life is the mar-vellous profusion of reptilian forms,—aquatic, amphibious, terrestrial, and aërial,—often of huge size, and occasionally of orders to which we have now no existing analogue. Of the sea-saurians, often whale-like in size, we may notice the well-known forms—ichthyosaurus, plesiosaurus, and pliosaurus; of the amphibious crocodilians—teleosaurus and crocodilus; of the lizard-like genera—lacerta and nothetes; of the turtle family—chelone and platemys; of the dinosaurians, or gigantic terrestrial forms—iguanodon, megalosaurus, and hyælosaurus; and of the winged sau-rians, or those fitted for aërial flights, the pterodactylus,

or wing-fingered reptile. In the seas and estuaries, on the shores and river-banks, over the dry land and through the



Ichthyosaurus communis.

forests, sunning themselves on cliffs, or winging their way through the air, these oolitic saurians must have swarmed in myriads. They are, indeed, the dominant and characteristic vertebrata of the period; and whether in point of numbers, magnitude, or variety of form, have never been paralleled either in any preceding or subsequent epoch. Birds, so doubtfully evidenced by their footprints in the Trias and Permian, now leave their remains (bones and impressions of feathers) on the fine-grained lithographic limestones of Germany; these ancient birds, (archæopteryx,) having the vertebræ of the tail elongated and feathered on either side, and their bills, perhaps, furnished with teeth, as in the fishes and reptiles. Higher than birds, the teeth and jaws of several small marsupial mammals (that is, pouched mammals like those of Australia) have been found in the oolites of England and Germany, (amphitherium, triconodon, phascalotherium,) indicating that during the oolitic period every class of life, with the exception, perhaps, of the higher mammalia, had made their appearance on the globe.

Strata of oolitic age occur in various countries, but rarely in large and unbroken areas. It is typically developed in England, where it occupies a broad belt stretching from the Yorkshire coast on the one side to that of Dorset on the other; in the Hebrides and north of Scotland; in Germany, Switzerland, and France, where it is usually spoken of as the "Jurassic system," from its development in the region of the Jura; in Italy, flanking the Apennines; in India and the Indian Archipelago, with

workable seams of coal; in New Zealand, and doubtfully with coal in Australia; and pretty fully, with thick beds of coal, in Virginia and some of the Southern States of America. The Wealden, as an estuarine formation, is much more limited and local; and with the exception of its continuation on the west coast of France, and some analogous strata in Hanover and Westphalia, its existence in other areas is unknown, or at least highly problematical. Wherever the true marine strata of the Lias and Oolite occur, they consist largely of limestones and calcareous shales, and are characterised by a profusion of star-corals, pentacrinites, gryphites, ammonites, and belemnites; but especially by those huge sea-saurians, land-saurians, and flying-saurians, whose numbers and variety have led to the use of such phrases as the "age of reptiles," the "reign of reptiles," and other kindred expressions. Seas of moderate depth and extent, and enjoying a temperature fitted for the growth of corals and encrinites; estuaries, lagoons, and mud-banks adapted to aquatic and amphibious reptile-life; river-banks and sunny shores congenial to terrestrial and aërial saurians; and a climate suited to the luxuriant growth of cycads, zamias, tree-ferns, and palms, appear throughout to have been the ruling conditions of the epoch. Though little affected by igneous action in the area of England, the system, both on the continent of Europe and in the Indian Archipelago, gives evidence of contemporaneous as well as of subsequent disturbance in interstratifications, metamorphic changes, upheavals, and disruptions.

Among the industrial products of the system may be mentioned excellent building-stones, paving-stones, and roofing-flags; limestones, marbles, and lithographic slabs; alum shales and fuller's earth; ironstone in bands and nodules; and in many areas jet and bituminous coal—the latter in seams often of great but of somewhat irregular thickness. The physical features of oolitic districts, where undisturbed by igneous upheavals, as in England, consist of easy undulations, the limestones and harder strata forming hills and rounded heights, while

the softer shales and clays have been worn out into fertile flats and valleys.

Such are the more prominent features of the lower and middle Mesozoic systems—the Triassic and Oolitic—as developed in Europe, and in particular as they occur within the British Islands. The Trias, consisting mainly of reddish sandstones, pebbly conglomerates, and mottled shales and marls, with imbedded masses of rock-salt and gypsum, would seem to indicate the existence of shallow and variable seas of deposit—shallow, inasmuch as sandstones and conglomerates are shore and beach formations; and variable, as detached masses of rock-salt and gypsum imply the repeated severance and re-union of certain tidal areas. As a life-system, the Trias is by no means prolific—a circumstance which may have arisen either from the composition of the waters in which so many salts and oxides were present, or from the less preservative character of the red sediments in which they were originally imbedded. As it is, the organic remains are eminently marine, and occur chiefly in the calcareous strata; the only indications of amphibious and terrestrial existence consisting in the scattered bones and teeth, and, above all, in the footprints, of reptiles. These footprints mark in great variety the surface of the flaggy sandstones—shewing how their owners wandered along the sandy and muddy shores, how these sands and muds got sun-dried and sun-cracked, and how they were again covered over by newer sediments which filled up the impressions, thus retaining mould and cast as perfectly as on the day they were implanted. In the Triassic areas of Europe vegetable remains occur chiefly in drifted and scattered fragments; but in other countries, strata supposed to be of the same age imbed seams of coal—shewing in this, as in other instances, how erroneous it is to generalise from local and limited phenomena.

In the Oolitic or Middle Mesozoic system we have a vast profusion of mixed sediments—sandstones, calcareous sandstones, limestones, calcareous shales and clays, bituminous shales, coals, and ironstones. These, in the lower formations of the Lias and Oolite proper, are eminently marine, and charged with marine organisms; but in the upper formations, or Wealden, they indicate fresh-water or estuarine conditions, and are characterised mainly by fresh-water and terrestrial remains. Whether in European, Asiatic, or American areas, the geographical conditions of the system appear to have been highly favourable to exuberance of life; hence the seas of the period swarm with zoophytes, shell-fish, and fishes; the estuaries, lagoons, and marshes abound in reptiles—aquatic, amphibious, and terrestrial; while the plains and higher lands are clothed with tree-ferns, cycads, zamias, palms, and coniferous trees, and tenanted by gigantic herbivorous reptiles, by flying reptiles, birds, and small marsupial mammals allied to the wombat, the opossum, and kangaroo. Indeed every rank of life, with the exception of the grains and true timber-trees, the higher birds, and the higher mammals, seem to have been represented in this period—shewing the great advance that had taken place in the manifestations of vitality as compared with those that appear even in the higher of Palæozoic systems. A panorama of wide-spread seas and inland-stretching estuaries, of low-lying islands and open continents enjoying a sub-tropical climate, distinguish the physical aspects of the Oolitic era; while palms and cycadaceous plants, ammonites and cuttle-fishes, gigantic reptiles and marsupial mammals, are the dominating features in its vital phases.

VIII.

UPPER MESOZOIC: CRETACEOUS OR CHALK SYSTEM.

Though convenient, for the sake of description, to arrange the Mesozoic Cycle into lower, middle, and upper, it must be borne in mind that there is no break or cessation in the great evolution of life, but merely local changes in the relations of land and water, by which certain species have been compelled to shift ground, or, it may have been, altogether extinguished, and by which the nature of the sediments has been altered. Such changes give rise to new formations and systems; and just as they are rapid or gradual, local or extensive, so will greater or less differences appear—not only between the sediments, but between the fossils of successive periods. In this way formations that are well-defined in the areas of Britain may insensibly graduate into each other in other regions; and thus the student should ever remember that our "systems" and "periods" are to a certain extent artificial and provisional. Ranking the Triassic system as *Lower* Mesozoic, and the Oolitic as *Middle*, the Cretaceous forms the *Upper* section; and though its marine beds are clearly separable from the estuarine strata of the wealden in England, yet in other countries where the wealden is absent, there is often no very clear line of severance between the chalk and subjacent oolites. Indeed, by many continental geologists the Wealden and its contemporaneous marine strata are regarded as the basement beds of the Cretaceous system—thus shewing still further the necessity of avoiding all sharp lines of demarcation between conterminous formations.

CRETACEOUS OR CHALK SYSTEM.

Taking the succession as it appears in the south of England, the Cretaceous or Chalk system (Lat. *creta*, chalk) immediately overlies the upper clays and sands of the Wealden. As a rock-formation, it is composed of cretaceous, argillaceous, and arenaceous sediments,—that is, of chalky, clayey, and sandy strata,—the first prevailing in the upper portion, and the two last in the lower. The lower portion of the system is known as the *Greensand*, and consists of green or ferruginous sands and layers of indurated sandstone, with a thick intervening bed of a bluish tenacious clay, locally known as the "gault" or "golt." The upper portion, on the other hand, is mainly composed of thick beds of *Chalk*, with or without flints, and separated from the greensand by a stratum of earthy or clayey chalk-marl. On tabulating the whole series as it occurs in the south of England, we have the following intelligible synopsis:—

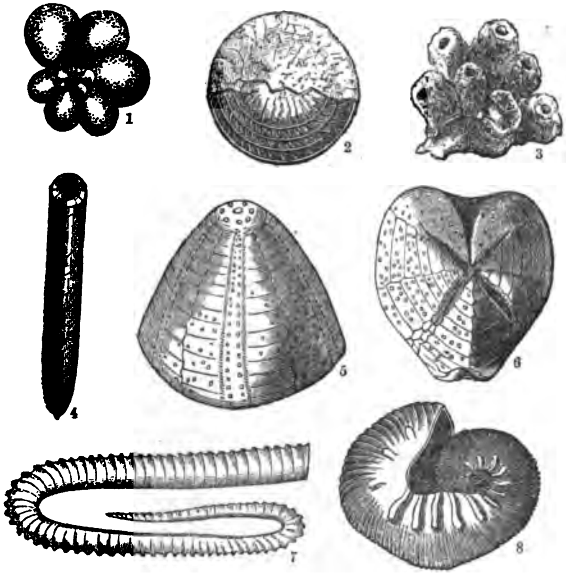
CHALK.	*Upper Chalk.*—Generally soft white chalk, with numerous flint nodules arranged less or more in layers.
	Lower Chalk.—Harder and less white than the upper, and with fewer flints.
	Chalk Marl.—Grayish earthy or marly chalk, with occasional harder bands and nodules.
GREENSAND.	*Upper Greensand.*—Beds of green and grayish siliceous sands, with indurated layers and nodules.
	Gault.—A local name for a bluish tenacious clay, which is sometimes marly or sandy.
	Lower Greensand.—Beds of green or ferruginous sands, with layers of cherty sandstone and fuller's earth.

Of course the preceding arrangement holds good only for the south of England; for in other parts of England, and more particularly on the continent of Europe, siliceous sandstones, grits, shales, and seams of lignite occur; while in North America the chalk beds are represented by coralline and siliceous limestones, and the other strata by an indefinite alternation of sands and clays, imbedding lignites and seams of true bituminous coal.

As already mentioned, the fossils of the Chalk system are eminently marine—consisting notably of sea-weeds, sponges, foraminiferous organisms, corals, star-fishes, and sea-urchins, crustacea, shell-fish, fishes, and reptiles. The remains of terrestrial life are extremely rare, and it is only in a few localities that indications of land plants, birds, and the higher mammals have been detected. Commencing with the Flora or plant-life of the period, we may notice the occurrence of sea-weeds and confervæ (chondrites, confervites) throughout the various strata; and associated with the lignites, remains of tree-ferns, cycads, zamias, and pine-trees, (cycadites, pinites, strobilites.) With a smaller proportion, perhaps, of tree-ferns and cycadaceous plants, and a greater abundance of coniferous trees, the flora of the chalk bears a close resemblance to that of the oolite—shewing that while in some regions (as in Britain) conditions of soil and climate had become unfavourable to vegetable exuberance, in others (as North America) these conditions had experienced little or no change since the time of the upper oolites.

The Fauna, or animal-life, is extremely abundant, especially in those orders that inhabit the tranquil depths of marine waters. Among these the sponges and their allies occur in numerous and characteristic forms, (ventriculites, scyphia, siphonia); and the foraminifera in such profusion, (rotalia, textularia, orbitoides,) that a large proportion of the chalk is composed of their minute calcareous shields, just as we find the calcareous sands of the existing ocean largely made up of similar organisms. The corals are abundantly represented by many elegant forms, (trochocyathus, parasmilia, aspinopora); the crinoids in lessening numbers, (marsupites, pentacrinus); the star-fish in increasing genera, (goniaster, oraster); and the sea-urchins by an unparalleled exuberance of beautiful and varied forms, (cidaris, spatangus, ananchytes, galerites.) Indeed, these sea-urchins are among the most beautiful and characteristic of our English chalk-fossils—every plate and spine, and pore and tubercule being as distinctly legible as they are in the species of existing waters. The mollusca or shell-fish, as might be expected in a for-

mation so eminently marine, and so well fitted for their preservation, occur in every order, and in numerous genera



1. Globigerina; 2. Nummulite; 3. Cnemedium; 4. Belemnite; 5. Galerites; 6. Spatangus; 7. Hamite; 8. Scaphite.

and species. The compound polyzoa, (eschara, retepora); the brachiopods, (rhynconella, terebratula, crania); the simpler bivalves, (pecten, inoceramus); the curious massive forms, (hippurites, radiolites); the higher bivalves, (trigonia, cardium, venus); the univalves, (rostellaria, cerithium, natica); and the cephalopods, shell-clad, like the nautilus, (ammonite, hamite, baculite,) or shell-less, like the cuttle-fish, (belemnites.) The great flush of chambered shells, whether coiled like the ammonite, straight like the orthoceratite, or bent in grotesque shapes like the hamite, closes, however, with the chalk period;

and in all succeeding systems the naked cuttle-fish forms prevail. Annelid tubes, (serpularia, vermicularia); barnacles, with their valves all in place, (pollicipes, scalpellum); minute bivalved crustaceans, (cythere, cytherella); and the larger crab-like forms, (pagurus, myeria,) are common in the chalk-marls and greensands—all presenting closer resemblance to the articulata of the present day than did those of preceding formations.

The vertebrate life of the chalk period is represented by fishes of all existing orders, by reptiles, and occasionally by birds and true placental mammals. Of the fishes, we have numerous teeth of placoids, (lamna, corax); teeth, scales, and perfect specimens of ganoids, (lepidotus, macropomus); specimens of ctenoids, or the comb-scaled order, (beryx); and of the cycloids, or soft circular scales, (osmeroides.) Indeed, the ganoids and placoids are evidently on the wane, and the ctenoids and cycloids, to which most of existing fishes belong, are now, for the first time, decidedly represented in the rocky strata. The reptiles, whether marine, amphibious, terrestrial, or aërial, (plesiosaurus, chelonia, iguanodon, pterodactyles, &c.,) are identical with those of the wealden, if indeed we do not regard the wealden as the basement of the chalk rather than the capping of the oolite. Bird bones, apparently aquatic, have also been detected in cretaceous strata, (cimoliornis); and if anatomists be not mistaken, the bones of mammals that would indicate affinities so high in the scale of being even as the quadrumana or monkeys. And when it is recollected that the chalk system is so largely of marine origin, and that it is only in certain areas that we have evidences of terrestrial growth, we may well believe that many of the higher animals existed during the period, and that their remains would have appeared in cretaceous strata had there only been favourable conditions for their entombment and preservation.

The Cretaceous system, in one or other of its members, is largely developed in European areas—in the south and south-east of England, in the north of Ireland, in France, in the region of the Pyrenees, Alps, and Carpathians, in Poland, Russia, Sweden, and Denmark. In Asia its equi-

valents are found in the ranges of the Lebanon and Caucasus; and chalk fossils have been detected in Southern India. Strata of the same age, or at all events containing cretaceous fossils, have been met with in South America, at various points along the Andes; while in North America beds, apparently the equivalents of our gault and greensands, are known in Texas and the Southern States, in the prairies of the far North, and in Vancouver's Island, imbedding lignites and seams of true bituminous coal. Wherever the system occurs, and whatever its composition, it gives ample evidence of marine conditions—seas somewhat shallow and variable during the deposition of the greensands, and of greater depth and tranquillity during the elaboration of the chalks. The observer cannot cast his eye over a suite of its fossils, its sponges, foraminifera, sea-urchins, crabs, shell-fish, and fishes, without being impressed with the prevalence of oceanic influences; it being only in limited areas that lignites and coals bear evidence of terrestrial conditions favourable to the development of a local and by no means exuberant flora.

The industrial products obtained from the system are—chalk, which is used for all the purposes of a limestone; marble, where the chalk has been metamorphosed by the action of heat; flints for pottery and other uses; fuller's earth; coprolites or phosphatic nodules, from the greensand, for manure; sand and firestones; and, where they occur in available thickness and purity, lignites and coals. The physical aspect of chalk districts varies, of course, with the portions of the system that may be developed. Where the greensands and clays alone occur the landscape is flat, and but little relieved by dry sandy ridges; but where the chalk is found in full force, as in the south of England, we have a succession of rounded hills and valleys,—"downs" and "wolds," as they are locally termed,—remarkable for their dry open pastures and extensive sheep-walks. Where the system has been disturbed by igneous eruptions, as in the north of Ireland, (Giant's Causeway,) and in the Alps and Pyrenees, it partakes of all the undulations and irregularities of trap or volcanic

districts, and loses its own stratigraphical character in the disruptions and displacements to which it has been subjected.

Such are the leading features—lithological and palæontological—of the Cretaceous system, whose formations, the greensand and chalk, or wealden, greensand, and chalk, constitute the upper portion of the great mesozoic life-cycle. In its mineral or lithological character it embraces sands, sandstones and grits, clays, fuller's earth and marls, and notably, in European areas, thick strata of soft earthy carbonate of lime, or *chalk*, imbedding frequent layers and nodules of flint. The sands and grits are such as may have been formed on open shores, the clays and marls in deeper water, the chalks, composed largely of the minute shields of foraminifera, in still greater and quieter depths, and the flints of aggregations of siliceous matter round sponges, sea-urchins, and the like, that were imbedded in the soft limy matrix of the chalk. Most of the fossils are of marine origin,—sponges, foraminifera, corals, sea-urchins, shells, crabs, fishes, and reptiles,—but along with these occur reptiles of amphibious, terrestrial, and aërial habits, indications of birds, and also of true mammals. Like all strictly oceanic deposits, the terrestrial remains are exceedingly few and imperfect, but combining these with what we know of the flora in its lignites and coals, we are led to infer genial conditions of climate on land, but seas in some areas opening to the influx of colder currents, and perhaps even of icebergs, which brought down boulders of granite and other rocks to be dropt in the chalky muds that were accumulating in the greater depths of the ocean. As a rock-deposit, there is no great difficulty in detecting the agencies at work in the accumulation of its strata; as a life-period, we perceive in its varied fossils a wider difference from the forms that peopled the

palæozoic and lower mesozoic seas, and a nearer and nearer approach to those that inhabited the waters of the tertiary, or even still survive in the seas of the current epoch. No graptolites, trilobites, eurypterites, or cephalaspides thronged its waters; no sigillaria, stigmaria, or lepidodendra were rooted on its shores; but sea-urchins, crabs, shells, and fishes in the former, and palms, cycads, and pines on the latter—differing, no doubt, from existing genera and species, but still so closely approximating that the palæontologist feels in every investigation a perceptible advance towards the life of a newer and more obvious cycle.

IX.

LOWER CAINOZOIC OR TERTIARY.

UNDER the Cainozoic cycle are arranged all those formations that have been accumulated since the close of the Cretaceous epoch, or which are still in process of accumulation. It comprises the Tertiary and Post-Tertiary or Quaternary systems—the former embracing all the older and more regularly-stratified clays, sands, limestones, lignites, &c., which occur beneath the Boulder Clay; and the latter all the more recent and irregular accumulations of sand, gravel, clay, marl, peat-moss, and the like, which have taken place since the time of the Boulder Clay, and which, in many lakes, estuaries, and seas, are still in course of formation. All the life-forms of the Cainozoic cycle belong to existing orders, and indeed comprise the living flora and fauna of the globe, with the exception of such genera and species as may have become extinct since the commencement of the cycle. Even in the oldest strata there is a *recentness* of aspect (as the term signifies) in all the fossil-forms, compared with that which pervades the fossils of the Mesozoic and Palæozoic; and the palæontologist feels he is dealing with a system of life, every phase of which is readily referrible to that which is now flourishing around him.

TERTIARY SYSTEM.

As already stated, the Tertiary system comprises all those stratified clays, sands, gravels, limestones, and lignites which lie between the Chalk and the Boulder Clay or Drift-beds of the Glacial epoch. The term has reference

to the classification of the earlier geologists, who, dividing the stratified crust into Primary, Secondary, and Tertiary formations, regarded as *Tertiary* all that had been formed since the deposition of the Chalk. The term is now restricted to the earlier and more regularly-stratified beds, such as those of the London and Paris basins, and in the lowest of which a large proportion of the fossils belong to extinct species; while the designation *Quaternary*, or *Post-Tertiary*, is applied to such accumulations as have taken place since the deposition of the Boulder Clay, and in which the fossil remains belong almost exclusively to existing species. As developed in Britain, the Tertiary system consists of such strata as the stratified clays, sands, and gravels of the London basin; the sands, indurated sands, marls, and siliceous limestones of the Hampshire basin and Isle of Wight; and the marls, shingles, and shelly coralline sands (usually known as the "Crag") of Norfolk and Suffolk. The London beds are charged with marine fossils; those of Hampshire with alternations of fresh-water and marine; and those of Norfolk and Suffolk, again, exclusively with marine. Taking the proportion of living and extinct shells which occur in these various groups, it is customary to subdivide the Tertiary system into four main stages—the eocene, miocene, pliocene, and pleistocene. These terms have reference to the percentage of existing shells—the smaller the proportion, the older, of course, are the strata that contain them. Thus *eocene* (from *eos*, the dawn, and *kainos*, recent) signifies that the proportion of living species is very small—so small as merely to indicate, as it were, the dawn of existing things; *miocene*, (*meion*, less,) that the proportion of recent shells is less than that of extinct; *pliocene*, (*pleion*, more,) that the proportion of recent is greater than that of the extinct; and *pleistocene*, (*pleiston*, most,) that the shells of this uppermost group belong for the most part to living species.

Arranging the British Tertiaries under these groups or sub-divisions, we have the following intelligible synopsis—the lower as they occur in the well-examined districts of London and Hampshire, and the uppermost (approxi-

mately) as it is scattered over the general surface of the country :—

PLEISTOCENE.	*Boulder Clay, or Boulder Drift.*—An irregular series of thick tenacious clays enclosing water-worn boulders of all sizes; of mounds and ridges of sand and gravel; or an admixture of clays, sands, and boulders, for the most part abraded and denuded from the rocks of the neighbourhood in which they occur.
PLIOCENE.	*Mammaliferous Crag* of Norfolk and Suffolk.—Consisting of shelly beds of sand and yellowish loam, with layers of flinty shingle, and generally covered with a thick bed of gravel, abounding in the bones of mammals; hence the name. *Red Crag* of Norfolk and Suffolk.—A deep ferruginous shelly sand and loam, with an abundance of marine shells. *Coralline Crag.*—A mass of shells and corals in calcareous sand; or compact, and forming flaggy beds of limestone, with bands of greenish marl.
MIOCENE.	Supposed, on palæontological grounds, not to be represented by any of our British strata, unless perhaps by the leaf-beds of Mull and the lignites of Antrim.
EOCENE.	*Fluvio-Marine Beds* of Hampshire and Isle of Wight.—Consisting of clays and marls, sometimes indurated, of sandy clays and subordinate layers of siliceous limestone. *Bagshot Sands.*—A series of marine sands, greenish sandy clay, and fissile marls. *London Clay.*—A brown or dark-blue or blackish tenacious clay, with layers of argillo-calcareous nodules. Layers of greenish sand, and masses of gypsum, and iron pyrites not unfrequent. *Bognor Beds.*—Consist of calcareous and siliceous nodules, or of coarse green indurated sand, with septaria and numerous marine shells. *Plastic Clay and Sands.*—Sand, shingle, mottled clays, and loam, with beds of rolled flints and marine shells.

While the preceding may be taken as sufficiently descriptive of the tertiaries of Britain, it must be borne in mind that strata deposited in limited and shifting seas, such as those of the tertiary epoch, will necessarily be very varied in character and composition. In the Paris basin, for example, there is a larger proportion of calcareous strata of

fresh-water origin, siliceous burrstones and gypsum; while in the Austrian series there is a larger proportion of clays and lignites. Again, in many basins there are thick developments of siliceous strata, like the well-known *tripoli* or polishing stone, almost entirely composed of the shields of diatoms; while in others, there are still larger calcareous aggregations, like the *nummulitic* limestone of Europe and Asia, and the *orbitoidal* limestone of America, almost wholly made up of the shells of foraminifera. On the whole, and wherever they occur, tertiary strata may be said to consist of clays and sands, soft sandstones, shell-beds, shell-rocks, and calcareous sandstones composed of comminuted shells and corals, marls, foraminiferal and organic limestones, burrstones, occasional bands of clay iron-ore, and seams of lignite. In general, they are less consolidated than the more ancient formations, though, through infiltrations of siliceous matter and metamorphic changes caused by volcanic heat, the rocks of certain areas are rendered as hard or even crystalline as palæozoic strata.

Rocks of tertiary origin occur in every region of the globe; but from the limited and variable areas (lacustrine, estuarine, and marine) in which most of them have been deposited, it is much more difficult to co-ordinate them with British equivalents than the older formations. It is enough for purposes of comparison to arrange them into *Lower*, *Middle*, and *Upper* Tertiary, and strata belonging to one or other of these great divisions have been examined in Europe, Asia, Africa, Australasia, and both Americas. Another obstacle to their arrangement into contemporaneous groups arises from the fact that their fossils, belonging more or less to existing species, partake of the geographical distribution that characterises the living flora and fauna of the globe—that is, as the plants and animals of the Old World differ from those of the New, those of the southern hemisphere from those of the northern, and those of one latitudinal zone from those of another; so among tertiary strata we find their fossils regulated by similar geographical causes, and each basin presenting a similarity of flora and fauna to those at pre-

sent flourishing in the same areas. All this prevents minute contemporaneous identifications, and an arrangement into lower, middle, and upper is, perhaps, all that can be philosophically attempted in the meantime.

The igneous rocks associated with the Tertiary system are all of volcanic origin, and can be readily traced either to volcanoes still in activity, or to cones and craters that leave no doubt as to the nature of the source from which they emanated. They consist of trachytes or felspathic graystones, basaltic lavas, tufas, and similar compounds, and are well exhibited in such districts as Auvergne in Central France, the Rhine, Switzerland, Hungary, and Italy. They are found also in Asia Minor, in India, Further India, Australia, and New Zealand, alternating with clays, sands, and lignites, either as overflows of lava, or as showers of cindery or scoriaceous matter. Wherever, or in whatever form they occur, they produce among these newer strata dislocations, upheavals, and metamorphic changes precisely similar to those produced among the older strata by the traps and porphyries. The older the tertiaries, the more trappean, of course, are the associated igneous rocks; and the newer they are, the more closely do these resemble the products of existing volcanoes.

As already stated, the organic remains of tertiary formations belong to existing types, and resemble more or less the living flora and fauna of the regions in which they occur. But, while this may be received as a general statement, it must ever be borne in mind that the occurrence of tertiary strata over such wide tracts of Europe, Asia, and the other continents, necessarily implies great differences between the lands and seas of that period and the lands and seas of the present day. With these varying distributions of sea and land, different climatic conditions must have prevailed; hence the flora and fauna of certain tertiary districts may exhibit forms differing widely from those now inhabiting the same area. Thus the lower tertiaries of England and France are replete with plants and animals that present a sub-tropical aspect; while in the uppermost or pleistocene portion remains of life are extremely rare, and everything indicates the existence of

rigorous and boreal conditions. With these explanations we may notice some of the more remarkable of tertiary fossil-forms, especially as they occur in eocene, miocene, and pliocene strata—leaving consideration of the pleistocene or boulder clay for another section.

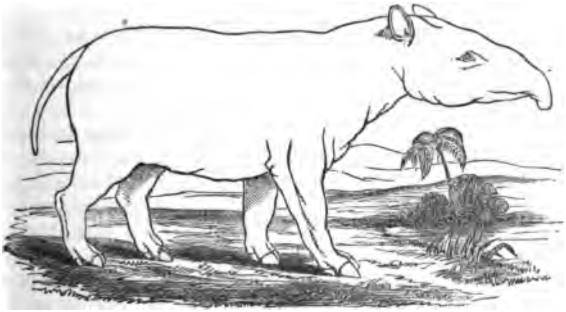
The Flora of European tertiaries, whether occurring in detached fragments among the clays and marls, or in compressed masses as lignites and brown coals, has scarcely received the scientific scrutiny it demands; but such of the leaves, fruits, and stems as have been examined would seem to indicate conditions of a genial, warm, temperate, or even sub-tropical kind. Mimosa-like plants, (mimosites); leaves like the fan-palm, (flabellaria); fruits like those of the nipa of Bengal, (nipadites); cypress-like twigs and cones, (cupressinites); unknown pods, (faboidea); and woody fruits of many kinds (carpolithes) are among those given in palæontological lists—all indicating warmer conditions, if not *in situ*, at least in the regions from whence the plants had been drifted. In the lignites of India, New Zealand, and North America, we have similar evidences of genial growth, but on the whole a general affinity to the existing flora of these respective areas. Much, however, depends upon the age of these lignites, which is by no means well determined; and just as they are of eocene, miocene, or pliocene date, so may the character of their plants be expected to differ from, or approximate to, those still flourishing in the same latitudes.

Like the flora, the Fauna of the true tertiaries, at least all along the middle latitudes of Europe and Asia, appear to indicate the existence of more genial conditions than those that now prevail over the same areas. Throughout the seas there is a prevalence of more southerly forms, and the terrestrial fauna abounds in genera that are now only known in sub-tropical latitudes. Corals, encrinites, cuttle-fishes, sharks, and marine turtles, abound in the waters; tapirs, elephantoid forms, antelopes, lions, hyænas, and monkeys throng the fields and forests. These sub-tropical forms occur, of course, most abundantly in the lower and middle tertiaries, for in the upper or plio-

cene stages, the fauna approach nearer and nearer to that of the current epoch. As regards the mollusca, this gradation is sufficiently indicated by the terms eocene, miocene, &c.—the eocene containing only from 1 to 5 per cent.; the miocene from 20 to 30; the pliocene from 60 to 80; and the pleistocene as many as 90 to 98 of existing species. In this case the marine invertebrata—the foraminifera, corals, sea-urchins, annelids, barnacles, crustacea, and shell-fish—are in a great measure the same as those of existing waters; and their specific divergences will be best understood by studying them *en suite* with those of the current epoch. The same remark is still more applicable to the land and fresh-water shells, which, in a majority of instances, are undistinguishable from those of the present day. Of vertebrate forms—fishes, reptiles, birds, and mammals—there is a great exuberance in the Old World tertiaries; and these, for the most part, belong to extinct species. Of marine fishes we have the remains of rays, (myliobates,) sharks, (lamna,) saw-fish, (pristis,) sword-fish, (cœlorhynchus,) sturgeon, (accipenser,) and the like; and of fresh-water forms—perch, carp, and mullet. Of reptiles, the most abundant are marine and fresh-water turtles, (chelone, emys, trionyx); species of crocodile and gavial; and remains of sea-snakes, (paleryx and palæophis.) Of birds, whose remains occur very sparingly in every formation, several aquatic and wading species have been detected in European tertiaries; but in general these remains are so fragmentary that no very definite affinities can be instituted, and palæontologists can only assign to them a temporary and provisional designation. Of mammals we can speak with greater certainty; and as these, in general, are more or less related to the fauna of the present continents, it may be convenient to consider them under this geographical aspect—premising that the more ancient tertiaries contain, of course, the most divergent forms, and that the remains occur not only in stratified deposits, but in bone breccias, limestone caverns, and other preglacial drifts.

In the eocene and miocene strata of Europe, for instance, we have a great number of pachydermatous animals—

allied to the tapir (palæotherium) and the elephant, (mastodon,) to the river-hogs (chœropotamus) and to the rhinoceros and hippopotamus, (acrotherium and archæo-



Palæotherium magnum.

therium); while a still greater number seem intermediate between the pachyderms and ruminants, (anoplotherium, xiphodon, dichodon,) and to which there are now no existing analogues. Indeed these *intermediate forms*—that is, genera partaking of the character of two adjacent orders—is one of the notable features of the Tertiary epoch. Not that such a feature did not exist in prior epochs, but that manifesting itself in mammals, it becomes more marked and suggestive than in the reptiles, fishes, or invertebrata. All the other orders—whales, rodents, carnivora, insectivora, bats, and monkeys—are also represented by extinct species; and genera now existing in Africa, as elephant, rhinoceros, hippopotamus, giraffe, lion, and hyæna, seemed to have thronged the plains, lakes, and river-banks of tertiary Europe. We know too little of the tertiaries of Africa to arrive at any conclusion as to their distinctive fauna; but in Asia we find gigantic elephantine forms, (mastodon, mammoth,) forms partaking of ruminant and pachydermatous characters, (sivatherium, bramatherium,) huge turtles (colossocheilys) and crocodilians, all differing from the existing genera of that continent, but assuming

more or less a resemblance to its living fauna. As with the Old World so with the New: North America has its mastodons and zeuglodons; and South America the gigantic prototypes of its existing sloths, armadilloes, llamas, and other mammals. Even Australia has its gigantic marsupials (diprotodon) and reptiles—not perhaps exactly contemporary with the palæotheres and mastodons of Europe, but prior, and that for a long period, to the living fauna of that island-continent.

The exuberant flora and fauna of the early tertiary periods (eocene and miocene) gradually passed away; and during the later, or pliocene age, the lands in the northern hemisphere seem to have been gradually sinking, and a less genial climate beginning to prevail. The plants assume a merely temperate aspect, (chestnut, sycamore, laurel, oak, &c.); the marine invertebrata are, in large proportion, the same as those of existing temperate or warm-temperate seas; and the terrestrial fauna now appear in greatly diminished numbers and humbler dimensions. The great flush of gigantic forms is past; the exuberance of intermediate genera—that is, exhibiting characters belonging to two or three adjacent orders—is over; and everything betokens the gradual approach to the icy and ungenial epoch that was about to ensue.

The Boulder or Glacial Drift.

Under this head we comprehend all those extensive accumulations of clay, sand, gravel, and boulders which cover the true tertiaries of the northern hemisphere, but which, from the nature of their clays and polished boulders, and the smoothed and furrowed rock-surfaces on which these rest, cannot be ascribed to the operation of agencies now at work within our latitudes. Such accumulations are found in Europe, Asia, and in North America, from the present limits of perpetual ice southward to the 43d or 44th parallel of latitude. They consist partly of stiff tenacious clays, through which are scattered indiscriminately rounded and polished blocks of all sizes, from that of ordinary pebbles to boulders many tons in weight;

partly of mounds of sand and gravel; and partly of boulders, either piled in masses, or resting detached (perched blocks, as they are called) on high and exposed situations. In most instances these boulders are not only smoothed and rounded, but are scratched and striated in straight lines, as if they had been forcibly moved in one direction along resisting rock-surfaces; and these surfaces (where the rock is sufficiently hard to retain) are in turn smoothed and cut in long lineal grooves, apparently by the blocks that passed over them.

The accumulation of such masses of clay, with boulders indiscriminately mingled through it, is evidently no ordinary deposition from water; and by no currents, or combination of currents, can we account for the transport and position of the perched boulders, many of which are forty and sixty tons weight, and miles removed from the cliffs from which they were detached. There is only one set of forces or agencies with which we are acquainted by which these phenomena can be satisfactorily accounted for, and these are glacier-ice on land to wear, smooth, furrow, and remove, and icebergs to float and transport to a distance. Not merely glaciers, such as we find on the Alps and other lofty mountains, but an ice-mantle, like that of Greenland and the Arctic islands, by which the whole land is enveloped, and by which the rocks are smoothed and furrowed, as its enormous weight, year after year and century after century, presses downward and outward to the shores. By these means—by glaciers in the upper glens and gorges to wear, smooth, and form moraines of sand and gravel; by a general ice-covering, to glacialise the surface, and carry polished blocks and triturated debris along with it as it crept irresistibly shoreward; and by icebergs, which are the more seaward and detached fringes of the general ice-mantle, to transport still further, and drop their burden of boulders and debris as they melted away—we can in a great measure account for all the phenomena of the so-called Boulder or Glacial period.

It would seem, therefore, that towards the close of the pliocene period the genial climate that had prevailed throughout the earlier tertiaries began gradually to give

way, and to be superseded by one of a more rigorous nature. What had been the proximate cause of this we cannot yet determine, but we see in the gradually-decreasing flora and fauna of the pliocene abundant evidence of its approach. The cold increases, and all the higher lands are covered with snow and glaciers; the flora and fauna succumb, and only such species survive as can gradually remove to more southern latitudes; hence the great paucity, or even total absence, of organic remains in the clays and gravels of the boulder epoch. Along with this increasing cold, the land seems to have gradually subsided to the extent of 1600 feet or more, for at this elevation we discover evidences of marine transport and shells; and again, after a long period, to have as gradually risen above the waters. The later stages of this uprise are to be seen in the old sea-margins, or raised beaches, that fringe the shores of the northern hemisphere, and in some of which (the Clyde clays, &c.) we still detect the shells and other reliquiæ of a boreal or glacial ocean. Beyond these shells, and a few scattered bones of whales, seals, divers, and other northern forms, organic remains are all but unknown in true glacial accumulations; and the drifts containing bones of mammoth, mastodon, hippopotamus, rhinoceros, &c., are either to be ascribed to the close of the pliocene or the earlier portion of the post-tertiary epoch.

The commingling and reassortment of accumulations that have taken place in consequence, *first*, of the gradual subsidence of the land, and, *second*, through its subsequent elevation, often renders it impossible to determine the relative age of certain drifts; but, generally speaking, the true boulder clays, partaking of the colour and mineral composition of the rocks on which they rest, and the moraines of sand and rubbly shingle, can be distinguished from the pre-glacial and post-glacial deposits. The evidences of ice-action in rounding, smoothing, and striating the boulders and pebbles, the unsedimentary aspect of the sands and gravels, and the total absence of organic remains, are points which, if well considered, will seldom fail to enable the observer to discriminate between the

true Boulder or Glacial Drift and other marine or fluviatile drifts of earlier or later epochs.

Such are the leading features of the Tertiary system, as usually arranged into eocene, miocene, pliocene, and pleistocene periods; or, more familiarly, into lower, middle, upper, and boulder-drift formations. In the lower and middle divisions we perceive over wide areas, both in the Old World and in the New, abundant evidence of genial conditions of life and growth. The lands along the river-banks, lakes, and shallow seas are thronged with sub-tropical and warm-temperate forms, whose remains are now preserved to us in the clays, silts, sands, marls, limestones, and gypsums of these areas of deposit. In the sands, gravels, and clays of the upper division we perceive a gradual declension of these life-forms, both in size and numbers; and ultimately, during the period of the boulder-drift in the northern hemisphere, their utter disappearance.

During the eocene and miocene periods there exist but a small proportion of existing species; but in the pliocene and pleistocene existing forms predominate, and we are insensibly led into the plant-life and animal-life that now adorns the terraqueous surface. A notable feature in the terrestrial fauna of the early tertiaries is the number of gigantic and intermediate forms—a feature that ceases to characterise the later stages, and appears still less in the current epoch. In the earlier tertiaries the genera and species seem to have had a wider range of existence; during the later formations they become more localised, and gradually assume the distribution that belongs to the present. In the northern hemisphere, at least, this continuity is interrupted by the incidence of the Glacial Drift, which marks a long period of icebound lands and frozen seas inimical to exuberance of life,

though perhaps, as in the Arctic regions of the present day, migrations took place during a brief summer of certain races, whose bones occur in anomalous drifts, which are by some regarded as pre-glacial and by others as post-glacial. In course of time the Glacial era passes away. the lands and waters gradually assume the grand outlines of their present distribution, and the existing order of nature is established.

In the recurrence of these warmer and colder periods over the same latitudes, so clearly established by the history of the Tertiary, Glacial, and Current epochs, we perceive the existence of a great cosmical law that must have operated during all preceding geological epochs; and should thus be prepared for the discovery of similar alternations during the earlier formations. Land and water —high and low, genial and ungenial—has been the order of recurrence in all times past; and by bearing this fact in mind, phenomena in the stratified crust become intelligible, which would otherwise remain anomalous and inexplicable.

X.

UPPER CAINOZOIC OR POST-TERTIARY SYSTEM.

AFTER the deposition of the Boulder Drift, the land and water in the northern hemisphere seem to have assumed very nearly the same distribution that characterises them at the present day. The land, no doubt, stood considerably lower in the water, for almost every coast is marked by terraces, or ancient shore-lines, indicative of uprise; and in this case some islands may have made their appearance, and the land, generally speaking, may have gained somewhat upon the water, but, on the whole, the same contours prevailed, and the existing order of things was gradually established. We know less of the condition of the southern hemisphere at this period, partly because it has been less minutely examined, but chiefly from the circumstance that it is much more largely occupied by water—Australia and the spur-like projections of Africa and South America being the only land-masses lying within its area. Even there, however, and especially in South America and Australia, several terraces of uprise are observable; and it may be taken for granted, within very narrow limits of error, that the Post-Tertiary period has been marked throughout by the same distribution of ocean and continent that at present prevails.

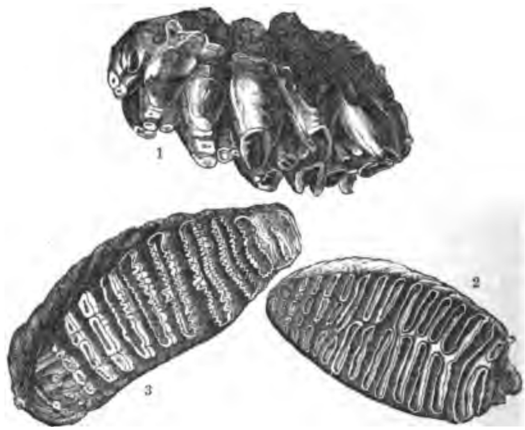
But while this may be accepted as true in general terms, it must be borne in mind that the agencies described in Chapter III. have been and are ever in incessant operation in the production of physical change. We may, therefore, expect that during the current period there have been numerous instances of local uprise and submergence; that deltas have been formed and lakes silted up; peat-mosses

and jungle-growth accumulated in swamps; shoals, banks, and reefs aggregated in the ocean; headlands worn down and bays shoaled up; ravines and valleys eroded; volcanic cones piled up; and surface irregularities produced by earthquake convulsions. Along with such physical mutations, we may also anticipate the local removal and extinction of certain species, the introduction of others, and, generally speaking, a progression analogous to that which has marked the course of all former geological epochs. To indicate these changes, physical and vital, is the purport of the present chapter; but as local details would occupy volumes, we shall best convey an idea of these Post-Tertiary or Superficial Accumulations, by arranging them according to the agencies by which they have been produced, or the nature of the medium in which they have been collected. We shall thus have river, lake, and sea deposits; vital, chemical, and igneous accumulations; or, speaking technically, fluviatile, lacustrine, marine, organic, chemical, and igneous formations, the nature of which we shall now briefly describe. And here the reader is reminded that the more intimate his knowledge of modern deposits, the better will he be prepared to interpret the ancient formations, and the causes concerned in their production.

Under the head of *Fluviatile* accumulations (Lat. *fluvius*, a river) are embraced all those formed through and by the agency of streams and rivers. Such accumulations are found chiefly along the courses of, and in the valleys occupied by, existing rivers. They consist of sand, gravel, and miscellaneous debris; but in the stiller reaches, and along the more level portions of valleys, of fine alluvial silt or alluvium. Where rivers have deepened and shifted their channels, these deposits constitute terraces, the higher of which are often of great antiquity. Beside the accumulations formed along the courses of rivers, there are generally alluvial deposits or deltas at their mouths, and these are frequently of great extent and thickness. Where a river discharges itself into a tidal estuary, the deltic deposit will be partly fluviatile and partly marine, and as this is the case with most of the larger rivers, their deltas are less fluviatile than fluvio-

marine. As fluviatile action has been going on uninterruptedly since the establishment of the existing seas and continents, the preceding accumulations will be of all dates from the present day back to the close of the Drift formation. And as rivers often shift their channels, and are subject, moreover, to floods and freshets, which tear up the older accumulations and commingle them with the new, it will sometimes be extremely difficult, if not impossible, to decide upon their relative antiquities. These and similar considerations must be taken into account in the investigation of river-deposits, and it is simply for want of this caution that erroneous conclusions are constantly being arrived at. Such being the nature of fluviatile deposits, we may expect to find them in all the larger and more level river-valleys—here as reaches of flat alluvial land, there as fringes of shingle and gravel; in one place as a single terrace of former elevation, in another as a succession of terraces; here as a compact delta in some estuary, there as a reticulation of marshes, river-mouths, and mud-banks gradually pushing forward into the sea. In this way have been formed the dales and holms and straths of our own islands, the river-plains of the continents, and all the deltas of such rivers as the Ganges, Nile, Niger, Amazon, and Mississippi. In the more recent portions of these deposits, the organic remains belong to plants and animals still flourishing in the surrounding districts; but in the older and deeper portions the remains occur in a *sub-fossil* or partially fossil state, and belong in many instances to plants and animals that have long since disappeared from the region, or are altogether extinct. Of such local removals we may instance the beaver, bear, wolf, wild-boar, reindeer, and primitive ox, whose bones occur in the river-deposits of our own islands; and of general extinctions we may point to the mammoth, mastodon, and woolly rhinoceros of the northern hemisphere; the megatherium, megalonyx, glyptodon, &c., of South America; and the dinornis or gigantic ostrich-like bird of New Zealand. As every great region of the globe is now characterised by its own special flora and fauna, so will the river-deposits of these regions

be characterised in future ages by their own peculiar fossils; and this consideration should induce great caution



1. Grinder of Mastodon; 2. of Mammoth; 3. of Asiatic Elephant.

when we attempt to co-ordinate the older formations, for we have no reason to presume that nature was guided in the Past by other methods than those that now govern the Present.

Under *Lacustrine* deposits (Lat. *lacus*, a lake) are comprehended all the sediments that usually accumulate in fresh-water lakes. Of course these will vary in mineral composition according to the locality of the lake, and in organic contents according to the latitude and altitude of the situation; but, generally speaking, in Europe alluvial silts, sandy clays, clay-marls, shell-marls, and bog-earth or peat-moss, are the common accumulations. The silts and clays and sands are carried in by streams; the marls arise partly from calcareous springs, but mainly from the shells of fresh-water mollusca; and the bog-earth and peat-moss are formed after the lake has been so far silted up and converted into a swamp or morass. In situations where the feeding streams carry little sedimentary matter, the

silting up of lakes must be an extremely slow process; but where they lie along the course of extensive valleys, and are fed by numerous hill-streams, the process must go forward at a much more accelerated rate. Most of our existing lakes are bordered by alluvial flats and swamps, which at one time were evidently occupied by their waters; and when we examine many of our alluvial valleys, we find that they are but a succession of silted-up lakes, and consist of all the sediments that usually characterise lacustrine areas.

The remains found in the lacustrine sediments of Europe are often very varied and full of interest. The peat-earths are usually replete with marsh-plants, as equisetums, bull-rushes, reeds, &c., and contain also portions of willow, bog-myrtle, birch, alder, and other trees that affect swampy habitats. The marls are replete with shells of lymnea, paludina, planorbis, cyclas, and other fresh-water genera; while the silts imbed the bones, horns, and antlers of creatures still living in Europe; or in the case of Britain, of many such as the gigantic Irish-deer, primitive-ox, wild-boar, wolf, beaver, and others that have long since become extinct in these islands. Along with these, the remains of man himself, and objects of human art, such as stone-hatchets, tree-canoes, bronze-implements, and the like, are not of unfrequent occurrence—all pointing to the time when what is now an alluvial flat was an open lake, over which rude tribes paddled their canoes, and in which they occasionally dropped the implements of the chase, or their instruments of warfare. Besides these, in the ancient alluvia of some European lakes, as those of Switzerland and Ireland, remains of ancient pile-dwellings (cranogges) have been detected — these also pointing to a distant antiquity when the physical conditions of Europe were widely different from what they are at present, and when it was inhabited by races whose manners and customs lie far beyond the reach of recorded history.

The *Marine* accumulations of the Current period (Lat. *mare*, the sea) embrace all those collected within the area of the ocean, whether formed along shore (littoral) or out in the deeper waters (pelagic.) The shore deposits consist

chiefly of sand, shingle, and marine silt—the sand accumulating in shallow bays, along which it forms low irregular tracts of sand-dunes; the shingle and gravel along the more exposed shores; and the finer silt in estuaries and the stiller recesses. The sandy tracts that occur along the bays of our own islands, and along the coasts of France, Holland, and Denmark, (often blown into grotesque dunes and ridges,) are strictly marine accumulations; and, the more inland portions, (now converted into cultivated fields and pasture lands,) are of high antiquity. The same remark is also applicable to the "silts" and "warps" of our estuaries—the older portions of which have long since been reclaimed from the waters, and converted into alluvial plains of great fertility. The organic remains found in such accumulations are chiefly marine—shells, bones of fishes, aquatic birds, seals and whales; but, as might be expected, terrestrial plants and animals are by no means unfrequent. In the newer deposits, the remains belong to species inhabiting the adjacent waters; but in some of the older, they belong to species that now live in distant seas—thus shewing changes of condition and climate since the commencement of the current epoch. The older marine silts, or "brick-clays" of the Clyde and Forth, are replete with shells now extinct in British seas, but which are still living in Arctic and sub-Arctic waters.

Where gradual uprises of the land have taken place, these littoral deposits (Lat. *littus*, the shore-line) constitute the "ancient sea-beaches" of the geologist—several stages or terraces of which are observable along the coasts not only of Britain, but of almost every country in the northern hemisphere. Organic remains are seldom preserved in the loose and open material of these raised beaches; but where they do occur, they indicate either slight variations of species, or belong to species that are now not to be found along the existing shores. In general, (at least in the northern hemisphere,) the sea-board exhibits only terraces of uprise or ancient beaches; but in one or two instances we have also evidence of depression in what are termed "submarine forests"—that is, layers of peat and forest-growth, which occur along shore con-

siderably beneath the existing tide-levels. These submerged forests, which may be seen at various points along the shores of England and Scotland, must have grown on land beyond the reach of the tide; and the fact of their now being covered by the sea, is proof that oscillations of the crust—that is, uprises and depressions—are still in these latitudes among the operative causes of geological phenomena.

Of the pelagic, or deep-sea deposits, (Gr. *pelagus*, the deep sea,) we know very little from actual observation; but if we may infer from such soundings as have been made, they must be extremely varied in their composition—of vast extent, and in all likelihood of considerable thickness. Some shoals and banks consist of sand, others chiefly of broken shells, and some again almost wholly of the bones of fishes, seals, and similar marine vertebrata. In some depths the lead brings up dark fetid slime; in others comminuted shells and corals; and in some again a soft calcareous mud, almost wholly composed of the minute calcareous shields of foraminifera. Of course the bearers and sorters of these deposits are the tides and currents of the ocean; and as these are co-extensive with the ocean itself, and incessant in their action, the deep-sea deposits must be of great magnitude; and, in some instances, of great continuity and persistence. Another circumstance, and one which bears most intimately on our interpretation of the older formations, is that these ocean-currents, (the Gulf Stream, Arctic Current, Equatorial Current, &c.,) in their flow from one zone to another, must commingle the products of widely-separated regions—a phenomenon which may have occurred in former epochs, and which would be wholly inexplicable by the palæontologist, who regards every fossil-form as strictly pertaining to the locality in which it is imbedded.

Organic accumulations—that is, accumulations of vegetable and animal growth—may occur in rivers, lakes, or seas, and in this sense are either fluviatile, lacustrine, or marine; but we here consider them under a separate head, as best explaining their character and mode of formation. While vegetable debris is borne down from the

land by rivers, or swept from the shores, and mingled less or more with all ordinary sediments, the most obvious accumulations of a vegetable nature are peat-mosses, which occur in all the temperate and colder zones—cypress-swamps, like those occupying large tracts in the Southern States of America—and forest-growth, mangrove-jungle, and the like, which accumulate chiefly in low-lying tropical river-basins and estuaries, as along the Amazon, Orinocco, and Niger. Most of these accumulations are superficial and obvious in their mode of formation; but others—like our submerged forests, the tree-drifts of the Arctic islands, Siberia, and Arctic America, which are now overlaid by sands and clays and gravels—are more difficult to be accounted for, and are clearly of great antiquity. In whatever form these vegetable accumulations occur, they must be regarded as the coal-forming beds of the present epoch, just as the lignites of the Tertiary are the semi-mineralised peat-mosses and forest-growths of that era, and the coals of the Oolite and Carboniferous the fully-mineralised and metamorphosed vegetation of these still more distant ages. And just as the reader makes his acquaintance with existing vegetable drifts, peat-mosses, cypress-swamps, jungle-growths, and their modes of accumulation, so will he be the better prepared to comprehend the nature and formation of the coals and anthracites of mesozoic and palæozoic epochs.

Of animal accumulations the most obvious and extensive are those produced by the lower and more minute forms of life. They are chiefly marine, and consist of shell-beds, coral-reefs, infusorial and foraminiferal aggregations. Shell-beds are occasionally formed *in situ*, by the destruction of gregarious mollusca; but more frequently by the accumulation of dead shells, either drifted on shore or borne by currents to shoals and banks in the ocean. Coral-reefs, again, are secreted from sea-water by coral zoophytes, and occur largely in the Southern Pacific and Indian Oceans, where they present themselves either as long lineal "reefs" off shore—surround some islands as "barriers"—crown banks and rocks in circular form with enclosed lagoons as "atolls"—or rise up in

"ledges" and independent islets. Occurring over extensive areas, varying from 20 to 100 feet in thickness, and stretching at times for hundreds of miles in uninterrupted length, these coral-reefs are perhaps the most remarkable of organic formations; and are now largely contributing, as they have done in all time past, to the solid constituents of the globe. The foraminifera also, by the accumulation of their myriad microscopic shells, are forming in like manner submarine deposits, of whose extent we can only guess by their prevalence in almost every portion of the ocean. And as shell-beds, coral-reefs, and foraminiferal aggregations are now preparing the matter for future beds of limestone; so in many estuaries the infusorial animalcules, by the accumulation of their siliceous shields, are engaged in the preparation of flinty and cherty strata. There are few things in nature so wonderful as the aggregation of rock-matter on such a stupendous scale, by creatures so minute as to be invisible to the naked eye; and when we reflect on the slow rate of aggregation, there is none, perhaps, that more impresses the mind with the amount of time that must have lapsed since their commencement in the current era.

But while the minuter invertebrata are mainly instrumental in adding to the stony matter of the globe, the geologist must not lose sight of the minor accumulations composed of the bones and other reliquiæ of the vertebrate animals. These are "bone-banks," like that lying between the Faröe Islands and Iceland, and almost wholly composed of the bones of cod, ling, torsk, seal, and other creatures inhabiting these northern waters; the "osite," or bone-guano of the island of Sombrero, which is evidently an upheaved bone-shoal of great antiquity; the "osseous breccia," or bone-breccia, occurring so frequently in limestone fissures and caverns; the "ossiferous gravels," (Lat. *os*, a bone, and *fero*, I yield,) or gravels of certain valleys replete with the drifted bones of extinct and existing mammals; and the "guano" of tropical islets, which mainly consists of the partially-mineralised excrement of sea-fowls, interspersed with bones, eggs, and similar exuviæ. Such accumulations as the preceding

present themselves of all ages, and in all stages of consolidation, from the loose drifts of the current century to the hardened stalagmitic breccias of Sombrero, the Mediterranean, and our own limestone caverns; and from the drifted bones of the present day to the old gravels of Northern Europe and Asia, containing the bones of mammoth, rhinoceros, reindeer, musk-ox, &c.; the silts of America, containing mastodon, and megatherium; of Madagascar, containing eggs and bones of æpiornis; and of New Zealand remains of dinornis.

Whatever may be the effect of *Chemical* action within the crust in dissolving some strata, in consolidating others, or in the formation of mineral crystals and metallic veins, we see it principally at the surface in the production of calc-tuff and calc-sinter by calcareous springs, of siliceous sinter by siliceous springs, of various salts by saline springs, of bituminous exudations from coals and lignites, of bog-iron ore in marshes, and of similar analogous deposits. All calcareous or petrifying springs are incessantly depositing tufa and sinter along their margins, just as in caverns they produce stalactites and stalagmites; but it is only in such cases as the "travertine" of Italy where they produce rock-masses of sufficient magnitude to affect the superficial aspect. The same remark applies to siliceous springs, notable examples of which occur in the geysers of Iceland and the hot springs of the Azores; to bituminous exudations, like the pitch lake of Trinidad, the petroleum springs of Rangoon, and the oil springs of North America; and to saline incrustations and deposits, (common salt, nitrates of soda and potash, sal-ammoniac, &c.,) like the salinas of South America and the salt lakes of Central Asia. All these, and others of a similar nature, are incessantly adding to the mineral structure of the crust, if not notably in point of magnitude, at least instructively as to manner, and thus become invaluable to the geologist, in enabling him to interpret the phenomena of the more ancient epochs.

Among the most extensive accumulations and changes now in course of production on the surface of the globe

are those arising from *Vulcanism*, or that internal igneous action with which we associate the volcano, earthquake, and gradual uprise or depression of portions of the solid crust. To describe the amount of lava, scoriæ, dust, hot mud, or other rock-matter thrown out by such volcanoes as Etna, Vesuvius, and Hecla during times of eruption, would convey a very imperfect idea of the accumulation of igneous products that is yearly taking place within the vulcanic areas of the eastern and western hemispheres. It is enough to remember that between three and four hundred craters are in incessant activity, ejecting and accumulating igneous products, and that perhaps double that number have been in a similar state of activity since the commencement of the current era. In this way extensive additions must have been made to all the volcanic hills and chains in the world; and in this way, also, numerous islands must have made their appearance from the bosom of the ocean. The more recent ejectments—loose, dry, rugged, and barren—readily speak for themselves; but the more ancient—compacted, worn down by meteoric action, and clad with vegetation—are more difficult to decipher, and carry us imperceptibly back to the tuffs, trachytes, and basalts of the Tertiary epoch.

As with volcanic accumulation, so with earthquake convulsion. We know, perhaps, the amount of fracturing, upheaval, and depression that has taken place during the current century within such areas as Chili, the West Indies, Italy, Java, Japan, and other centres of convulsion; but beyond this date we have little of recorded value, and are left to infer from our acquaintance with the present what must have taken place during the earlier portion of the current epoch. We know, for example, that in 1822 the coast of Chili was suddenly upheaved to the height of eight or ten feet; that a similar sudden uprise of six or eight feet took place in North Island, New Zealand, in 1858; that in 1819 the Ullah Bund, in the delta of the Indus, was also suddenly upheaved to the extent of ten feet, while other adjacent tracts were depressed; and we have further read of the devastations produced by the West India, Java, Japan, and Sicilian

earthquakes; but beyond a few scattered facts, such as these, we have no historical record. Taking these, however, as ordinary illustrations of the amount of change that may be brought about by earthquake convulsions, we can readily conceive how greatly the superficial aspects of the earth must have been modified by such means since the commencement of the Post-Tertiary period.

By far the most extensive changes, however, that seem to depend on subterranean forces are those slow and gradual crust-motions by which some portions are upraised above, and others depressed beneath, the medium level of the ocean. Movements of this kind not only alter the relative distribution of sea and land, but by making the seas shallower or deeper, and the lands higher or lower, affect also the climate, the distribution of plants and animals, and ultimately the contours and profiles of the land. We can readily perceive the effect that would be produced by the uprise or depression of our own islands, even to the extent of fifty or sixty feet—how much of the shallow sea-bed and estuaries would be converted into dry land in the one case, and how much of our low-lying fens and carses would be covered by the waters in the other. That such movements have extensively taken place during the current period we have ample evidence in the old sea-margins or raised beaches of our own islands; in the well-known uprise of the Scandinavian peninsula, which is still going on at the rate of four or five feet a century; in the numerous terraces of uprise that fringe the coasts of Siberia, Spitzbergen, North Greenland, and all the islands within the Arctic circle, and which are strown to the height of nearly two hundred feet with the shells and bones of the existing marine fauna of that boreal region. As there is uprise in one region, so we may naturally expect depression in another; and the southern coast of Greenland, the Atlantic seaboard of the Southern States of America, and many of the islands in the South Pacific, have been adduced as evidences of this phenomena. Whether uprise or depression, we readily perceive in this kind of crust-movement the great distributor of sea and land in for-

mer epochs; and though we cannot determine the proximate cause on which it depends, we may rely on its obeying some law of periodicity as fixed and determinate as those which govern the more obvious ordainings of the universe.

The preceding pages present but a brief and very general outline of Post-Tertiary, Quaternary, or Recent accumulations. In our own islands the Boulder Drift forms a well-marked boundary between them and the Tertiary formations; but where this glacial drift is absent, the one system merges gradually into the other, and we can only class as Post-Tertiary those accumulations whose organic remains belong exclusively, or all but exclusively, to existing species. Consisting, as they usually do, of loose sands, gravels, clays, silts, and marls; of peat-mosses, swamp-growths, and soils; of shell-beds, coral-reefs, and infusorial accumulations; of calcareous, siliceous, and other deposits from springs; and of lava, scoriæ, and similar ejectments from volcanoes, it is all but impossible to treat them in order of succession, and we have accordingly arranged them under the agencies by which they have been mainly produced. In this way we have *fluviatile* accumulations produced through and by the action of rivers; *lacustrine* deposits formed in lakes and marshes; *marine* accumulations collected in seas and salt-water areas; *organic*, arising from the vital agency of plants and animals; *chemical*, through chemical actions and reactions, in contradistinction to mechanical deposits; and *igneous*, or those depending on subterranean heat and force for their production. When arranged in this manner, there is in general little difficulty in determining the older from the newer; and though we cannot assign chronological dates, we can at least determine the order of succession.

Following this succession, we find that while almost the whole of these superficial accumulations have been formed since the existing order of things was established, yet in some of the older deposits there occur the remains of animals either not now living in the same areas or altogether extinct. Thus in the older marine and estuarine silts of Britain we discover shells unknown in our seas, though still existing in more boreal waters; while many of our valley and lacustrine deposits contain the remains of animals (beaver, wolf, wild-boar, bear, reindeer, musk-ox, &c.) long since removed from these islands, and even in some instances (Irish-deer, mammoth, woolly rhinoceros, cave-bear, cave-lion, &c.) universally extinct. As in the limited area of Britain, so in the continents both of the Old World and New World we have similar removals and similar extinctions, thus proving, according to the present rate of progression, a vast antiquity for the accumulations that contain them. In some of the river-drifts of France and England stone and flint implements have been found side by side with the bones of these extinct mammals; but as all river-accumulations are more or less liable to disturbance and reassortment, some doubt still hangs over the question of man's contemporaneity with such early forms as the mammoth and mastodon. But however this question may be ultimately settled, there can be no doubt that the remains of man and of his works which occur in lake-silts, peat-mosses, bone-caverns, and the like, bespeak an antiquity far beyond the six or seven thousand years of the ordinarily-received chronology. Nor, even should it be proved that an early race of men hunted the gigantic Irish-deer, and speared the mammoth in the forests of pleistocene Europe, is Geology prepared to offer any definite assertion as to years and centuries. Its legitimate cultivators may feel convinced of the vast antiquity of those events; but they decline, in the present state of their science, to assign to them other than a merely relative chronology.

But waving all questions as to dates, we perceive that from the commencement of the Post-Tertiary system there has been a continual succession of physical changes—

small, it may be, in any given locality or for any stated period, but great in the long-run, and necessarily accompanied by changes in the vital conditions of the globe. We see, also, that during the same period plants and animals have undergone not only removals from one area to another, but even in some instances total extinction; and though, through the imperfections of science, the introduction of new races has passed unobserved, we may rest assured that, in the scheme of creation, birth and death, creation and extinction, are necessary and unfailing concomitants. We thus discover in the Post-Tertiary, as in all the prior epochs, a system of change and progress; and the better we understand these recent accumulations, the better will we be prepared to interpret the phenomena of the more ancient formations. Their nature, mode and rate of accumulation, the conditions under which they are formed, and the vital phases by which they are accompanied, is the most important preliminary knowledge to the study of Geology. They merge, in fact, into the physical geography of the present; and all Geology is but the physical geography of the world at its successive stages backward in time.

There is thus no break between the existing phases of nature and those of the long geological past. We pass from the present to the historical, and from the historical to the pre-historical; and both gradually descend into the geological, where the only records are those which nature has indelibly preserved in the stratified crust. The historical forms but the merest fraction of geological time—a single beat of the pendulum compared with the unnumbered ages whose chronology is registered in the systems and formations we have endeavoured to describe. And yet throughout the whole, from the Cambrian to the Present, we find the same agencies at work, similar phenomena produced, and the same vital plan sustained in all its countless and ever-diverging developments.

BRITISH STRATIFIED SYSTEMS.

Range	*Systems.*	*Groups.*	*Periods.*
OF VOLCANIC	POST-TERTIARY.	In progress.	CAINOZOIC.
		Recent.	
	TERTIARY.	Pleistocene.	
		Pliocene.	
		Miocene (?)	
		Eocene.	
RANGE OF TRAPPEAN ROCKS	CRETACEOUS.	Chalk.	MESOZOIC.
		Greensand.	
	OOLITIC.	Wealden.	
		Oolite.	
		Lias.	
	TRIASSIC.	Saliferous Marls.	
		Muschelkalk (?)	
		Upper New Red Sandstone.	
	PERMIAN.	Magnesian Limestone.	PALÆOZOIC.
		Lower New Red Sandstone.	
	CARBONIFEROUS.	Coal-Measures	
		Millstone Grit.	
		Mountain Limestone.	
		Lower Coal-Measures.	
	DEVONIAN.	Upper Old Red.	
		Middle ,,	
		Lower ,,	
RANGE OF GRANITIC ROCKS	SILURIAN.	Upper Silurian.	
		Lower ,,	
	CAMBRIAN.	Cambrian and Lewisian Schists.	
	METAMORPHIC.	Clay-Slate.	HYPOZOIC.
		Mica-Schist.	
		Gneiss and Granitoid Schists.	

STRATIFIED ROCKS OF EUROPE.

Groups.	*Systems.*	*Cycles.*	
Recent.	POST-TERTIARY.		
Post-Pliocene.			
Newer Pliocene.	PLIOCENE.	TERTIARY OR CAINOZOIC.	NEOZOIC.
Older Pliocene.			
Miocene.	MIOCENE.		
Upper Eocene.	EOCENE.		
Middle Eocene.			
Lower Eocene.			
Maestricht Beds.	CRETACEOUS.	SECONDARY OR MESOZOIC.	
Upper White Chalk.			
Lower White Chalk.			
Upper Greensand.			
Gault.			
Lower Greensand.			
Wealden.	OOLITIC, OR JURASSIC.		
Purbeck Beds.			
Portland Stone.			
Kimmeridge Clay.			
Coral Rag.			
Oxford Clay.			
Great or Bath Oolite.			
Inferior Oolite.			
Lias Marls and Shales.			
Lias Limestones.			
Upper Trias.	TRIASSIC.		
Middle, or Muschelkalk.			
Lower Trias.			
Magnesian Limestone.	PERMIAN.	PRIMARY OR PALÆOZOIC.	PALÆOZOIC.
Variegated Sandstones.			
Coal-Measures.	CARBONIFEROUS.		
Carboniferous Limestone.			
Upper / Lower	DEVONIAN.		
Upper / Lower	SILURIAN.		
Upper / Lower	CAMBRIAN.		
Crystalline Schistsd. .	METAMORPHIC.	AZOIC.	

STRATIFIED ROCKS OF NORTH AMERICA.

Stages.	*Sections.*	*British Equivalents.*
UPPER.	Peat-Mosses and Savannas. River Alluvia and Deltas.	POST-TERTIARY.
LOWER.	Superficial Gravels and Raised Beaches.	
UPPER.	Boulder Formation of the Northern States and Canada.	TERTIARY.
MIDDLE.	Clays and Sands of North Carolina, &c. Greensand and Marls of Maryland, &c.	
LOWER.	Limestones and Clays of the Carolinas, &c.	
	Yellow Limestone and Greensand of New Jersey, &c.	CRETACEOUS.
	Sandstones, Shale, and Coal of Richmond, Virginia.	OOLITIC (?)
UPPER.	Red Sandstones of Connecticut, Mass., &c.	TRIASSIC(?)
LOWER.	Do. of Chatham, N. Carolina, &c.,	PERMIAN (?)
UPPER.	Coal-formation, or Coal-measures.	CARBONIFEROUS.
MIDDLE.	Lower Carboniferous Limestone.	
LOWER.	Sandstones and Conglomerates of Pennsylvania. Gypsum, Marls, and Conglomerates of Nova Scotia.	
UPPER.	Old Red Sandstone.	DEVONIAN.
MIDDLE.	Chemung Rocks; Portage Sandstone; Genessee Slate; Tully Limestone; Hamilton Rocks; Marcellus Shales.	
LOWER.	Carboniferous Limestone; Onondago Limestone; Schoharie Grit; Caudagalli Grit; Oriskany Limestone.	
UPPER.	Upper Pentamerus Limestone; Delthyris shaly Limestone; Lower Pentamerus Limestone; Waterlime Rocks; Onondago Salt Rock; Coralline Limestone, Schoharie; Niagara Shale and Limestone.	SILURIAN.
MIDDLE.	Clinton Rocks; Medina Sandstone; Oneida Conglomerate.	
LOWER.	Hudson-River Rocks; Utica Slate; Trenton Limestone; Birdseye Limestone; Chazy Limestone; Calciferous Sandstone; Potsdam Sandstone.	
	Huronian Sandstones and Schists	CAMBRIAN.
	Crystalline Schists................................	METAMORPHIC.

XI.

GENERAL INFERENCES AS TO WORLD-HISTORY.

FROM what has been stated in the preceding chapters, it will be seen that the rocky crust of our globe presents a history of long-continued change and progress. To interpret this history, as recorded in the stratified and unstratified rocks, is the object of Geology; and that science best fulfils its function by restricting its inquiry to the facts which these rock-formations reveal. Speculations as to the origin of matter and the formation of the universe, unless as inferences from the observed structure of our planet, lie altogether beyond the pale of Geology; and all World-History deserving of the name, begins with the oldest stratified rocks, which evince, by their structure, composition, or organic remains, the causes which led to their production. It is true that these old strata are underlaid by the still older crystalline and metamorphic schists, but these schists bear no evidence of the conditions under which they were formed, and belong, therefore, to pre-geological rather than to geological time. Our science does not profess to present the history of this planet in one continuous narrative, from its origin up to the present day; but, beginning with existing conditions, traces back, stage by stage, as far as it can, the record that remains legibly registered in the rocky crust. Though the monuments become obscure, Geology still labours to reveal; but when they are utterly effaced, she closes her legitimate task and leaves the rest to cosmogony and conjecture.

Guided by these methods, all true Geology may be said to commence with the Cambrian strata—the first in which

fossils have been detected as evidence of the kind of conditions that prevailed on the surface of our planet. All previous to that period is obscure and unsatisfactory, and though we may feel convinced that the agencies now operating on the globe were in operation long antecedent to Cambrian times, yet we have no certain evidence of their methods, and are constrained to commence our history only where the record becomes obvious and legible. From the Cambrian up to the present day, the agencies concerned in the formation of the stratified rocks —the sandstones, shales, limestones, ironstones, and the like—are all more or less obvious, the seas and estuaries in which they were deposited discoverable, the lands from which they were derived can be indicated, and the plants and animals that flourished during each successive period can be restored with sufficient certainty to establish their relations, and to some extent also the geographical conditions under which they existed. The earth writes, as it were, her own record, and this we have only to examine with sufficient skill, to arrive at a knowledge of the various mutations she has undergone, and which, under the continuous operations of natural law, she is still undergoing.

The various systems and formations we have described, constitute the great sections and chapters of this history —a history of marvellous interest and duration, and only as yet beginning to be understood and appreciated. Young, however, as Geology is, and imperfect as are many of her methods, she has established the fact that the crust of this earth is undergoing incessant change, conformable to some universal, but as yet little understood, plan of progression. Sea and land have frequently changed places, slowly and gradually, but still decidedly; and under each variation, different geographical conditions have prevailed, and with each varying condition different races of plants and animals have peopled the lands and waters. Throughout the immense lapse of time indicated by the stratified formations, there has been no break or cessation; the same causes of change are still in harmonious operation, and we naturally infer that as in the Past and

the Present, so in the Future, other distributions of sea and land will arise, other physical conditions will be locally established, and along with these, other plants and animals will appear, perfectly adapted to the new conditions of existence.

Nor is it merely a panorama of incessant change that Geology reveals, but a progress from lower to higher —each ascending stage in time being characterised by higher forms of life, built up after a uniform plan, and belonging to the same great category of vitality. It is true that the geological record is by no means perfect; that out of the myriads of plants and animals that flourished in bygone periods, only a small proportion have been preserved in the stratified rocks, and that a still smaller proportion of those so preserved have yet been discovered by palæontologists. Notwithstanding this admitted imperfection, enough has been detected to prove the fact of progression from lower to higher forms; and by and by, as our discoveries extend and our scientific methods become more precise, enough will be revealed to indicate the nature of the law by which this progression has been, and is still in course of being, effected. In the meantime Geology has established the fact; Physiology and the cognate sciences are striving to discover a satisfactory explanation. Their endeavour is not to fathom the origin of life, and similar problems equally unattainable, but simply to trace the course of creation, and from a knowledge of that course to indicate the secondary causes employed by the Creator for its regulation and development.

In this task Geology, recent as it is, has made marvellous progress, and cosmical facts undreamed of by our forefathers are now familiar knowledge to the present generation. Our forefathers contented themselves with the patristic chronology of the earth; we now know, from the numerous physical mutations the crust has undergone, and from the repeated successions of plants and animals imbedded in its stratified formations, that it has existed, and been the theatre of life and enjoyment, for untold ages. It was formerly matter of belief that the existing

seas and lands were the same as those over which the sun first rose on the morning of his creation; it is now known that land and water have repeatedly changed places, and that every stratified formation in the crust is evidence indisputable, that the area over which it now spreads was at one time occupied by the waters. Along with the belief in the recent formation of the earth, existed also the doctrine of the recent origin of plants and animals; it has now been shewn by palæontology, the vast antiquity of certain forms of life, and the gradual extinction and appearance of race after race in long succession—so long that every geological cycle is characterised by its own special flora and fauna. Formerly it was the general belief that the forms of life now peopling the globe were the same in kind as those which had existed from the beginning; now palæontology has shewn that there has been a gradual ascent from lower to higher forms, and that the flora and fauna of the present day are widely different from those of any former epoch, the difference becoming greater with each descending stage in time. The secondary law which regulates this ascent from lower to higher forms is yet unknown to Geology; but whatever its nature, it embraces the whole scheme of vitality, from the lowest to the highest, and as it operated in the past, so the fair presumption is that it is operating in the present, and will continue to operate in the development of still higher forms for the future.

Such are some of the more obvious teachings of Geology—teachings which are every year receiving further extension and confirmation. It is by no means asserted that our science has either attained to perfect methods or arrived at ultimate truths; but so long as its deductions are founded on observed facts, it continues on the fair way to exactitude and certainty. By its efforts a totally new light has been thrown on the history of our planet; and instead of an orb a few thousand years old, permanent in its appointments, and prepared solely as a habitation for man, we now perceive that it has existed for untold ages, has been subject to incessant mutation under the operations of natural law, had been the abode

of myriad existences cycles before man was called into being, and may, under the operation of the same laws of progression, be the abode of higher existences when mankind has ceased to be. In fine, as modern Astronomy taught the right relations of our little orb to the rest of the universe, so Geology has thrown new light on the various appointments of this orb, and, in particular, on man's relation to the whole.

A science thus professing to read the long history of our planet, its numerous physical mutations, its successions of plants and animals, and its various geographical aspects in time, has necessarily many attractions to incite to its study. To the archæologist it opens an almost indefinite field of research ; to the botanist and zoologist it presents higher and wider views of life; to the philosopher a thousand themes of intellectual exercitation; and to the theologian new evidences at every turning, of creative wisdom, goodness, and design. Nor in an economical sense is its study less inviting, seeing how intimately man's civilisation and mastery over nature depends on a knowledge of the minerals and metals. In fact, without such knowledge the modern civilisation of Europe and America would have been impossible; all that relates to mechanical power, means of intercommunication, diffusion of information, and cheap production, being the direct results of mineral and metallic appliances.

The Earth's Crust, which forms the theme of this little volume, is thus at once the foundation of all geographical diversity, the varied habitat of plants and animals, the storehouse of the minerals and metals, the theatre of man's life-actions, and hence one of the most important subjects of his study and investigation. What we have given in the preceding pages is a mere sketch in outline, but such an outline, we trust, as may incite to the perusal of fuller works, and, above all, to the study of Geology in the great stone-book of nature. There can be no true progress in natural science without investigation in the field, and the sooner the student learns to corroborate and extend the statements of his text-book by his own observations, the more rapid and encouraging will be his advancement

His leisure hours may be few, but the objects of geological research are scattered everywhere beneath and around him; and though his immediate locality may appear uninteresting and uninviting compared with other districts, yet he may rest assured that a thorough local knowledge is by far the best training either for the examination of other fields or for the understanding of their descriptions by other geologists. Even where no further study or field-work is desired, this little volume may be of use in directing the reader to the marvellous history of the world he inhabits, and in supplying him with such an outline as his own skill might fail to deduce from the perusal of larger and more technical treatises. The main aim has been to furnish the non-scientific reader with such information as he could readily appreciate, but at the same time to present it in systematic form, so that it might become an available basis for further investigation and research in the case of those who may thereby be induced to prosecute the study of Geology.

INDEX AND GLOSSARY.

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